LESSON STUDY AND DEMONSTRATION CLASSROOMS: EXAMINING THE EFFECTS OF TWO MODELS OF TEACHER PROFESSIONAL DEVELOPMENT*

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I. INTRODUCTION

The creation of professional learning communities has been identified as a crucial step toward student success in mathematical literacy. By supporting the development of professional learning communities, teachers are able to continually strengthen their knowledge and skills in a supportive and cooperative environment. This study focuses attention on the necessity for innovative professional development which "creates [new] arrangements for professional work that supports continued improvement of teachers' knowledge and their pedagogical skills" (RAND Mathematics Study Panel, 2003).

The KPR GAINS research for 2008-09 was designed to look closely at the effects, including merits and challenges, of two different professional development strategies for mathematics teachers: lesson study (LS) and demonstration classrooms (DC).

The treatments ran simultaneously within the Kawartha Pine Ridge District School Board. Researchers and the school district collaborated to establish the design of the study. In this report, the findings of the study are reported with a predominant emphasis on case study interpretations using qualitative and quantitative data sources to support the cases.

2. LITERATURE REVIEW

The following is a discussion of the research which foregrounds this study.

2.1 Lesson Study – One Continuous Model for Professional Development

Lesson study, as undertaken in this project, is inspired by Japanese Lesson Study, an intensive professional development model that Stigler and Hiebert (1999) describe as a way for teachers to look at their own practice "with new eyes". It has been broadly described as a systematic inquiry into teaching practice, carried out by examining lessons. In Japan, lesson study is an activity that is both sanctioned and supported by the Ministry of Education (Fernandez, 2002).

As a professional development model, lesson study has garnered the attention of researchers and educators due to the fact that it "is embedded in the classroom and focused on students, it is collaborative and ongoing, and it is based on teachers' own concerns and questions" (Darling-Hammond & McLaughlin, 1995). In this way, lesson study is a teacher-led or teacher-initiated activity that has the potential to increase research-based knowledge that is critical to improving instruction (Lewis *et al*., 2006a). "Teachers engage in lesson study as researchers and scholars of their own classrooms. Their inquiries honour the fascinating and complex nature of teaching" (Stepanek, 2001).

The use of lesson study as an effective professional development tool has spread rapidly in the United States since 1999 (Lewis *et al*., 2006b). In Ontario, the Ministry of Education's Report of the Expert Panel (2004) cited lesson study as one activity that teachers may consider as they are developing a learning team, in which they identify challenges, determine possible solutions, discuss classroom strategies, share successes, and identify next steps.

Despite the ongoing activity in lesson study in Japan, and the recent activity in the United States, there are very few examples of researched case studies and related publications in North America (Fernandez & Yoshida, 2004). Therefore, there is a pressing need for expanding the knowledge base of lesson study beyond the existing case studies. Further, researchers are interested in the specific mechanisms of lesson study that enable teacher professional development to occur. Because lesson study is not carried out in any large-scale systematic way in Canada, there is little opportunity given to teachers to influence national educational policy (Fernandez, 2002) as there is in Japan.

2.2 Critical Components of Lesson Study

The lesson study working group of researchers of the Psychology of Mathematics Educators of North America (PMENA) identified four critical components of lesson study: Goal Setting, where the facilitator may assist in setting goals; Curriculum Planning, with as much support as appropriate; Implementation and Observation, where live watching of the lesson and focused observation are fundamental (including training on how and what to observe); and Debriefing/Reflection on the lesson study process itself (Bruce, 2007). The components that they cited were derived from the lesson study cycle outlined in a seminal article by Lewis, Perry and Murata (2006), as shown in Figure 1.

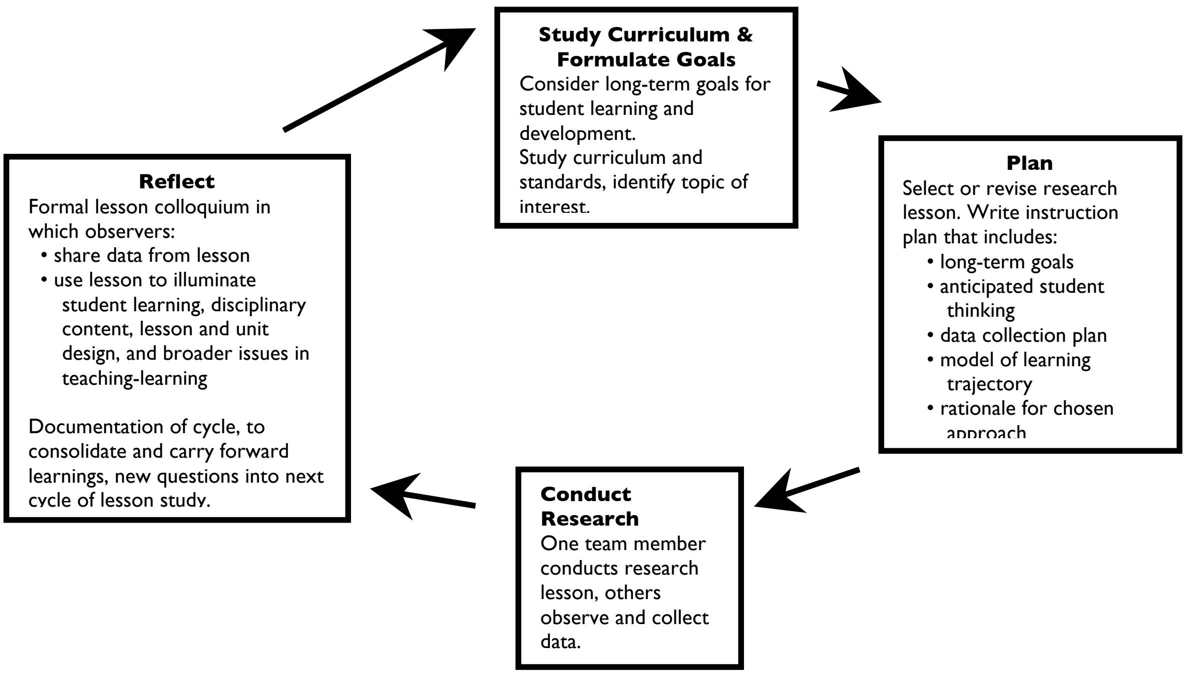

Figure 1. *The Lesson Study Cycle (Lewis, Perry & Murata, 2006)*

In the initial goal-setting phase, teacher participants begin by setting a goal for their students that they are aiming to address in their lesson. This is often something that is difficult for the students to learn, or difficult for the teachers to teach. In other words, "the desire to improve is stimulated by seeing what's *not* working" (Lewis *et al*., 2006b). Goal setting leads to an exploration for the best instructional strategies that could be used to achieve the goal (Fernandez, 2002). During this curriculum planning stage, the teacher participants need access to outside sources of knowledge – both print (e.g., textbooks, innovative materials, outside research articles) and human (e.g., outside educators, content specialists, researchers). Once the lesson is planned, teacher teams decide who will implement the lesson. The lesson is taught and observed, and a detailed debriefing session and reflection takes place. This debriefing period drives the continuation of the cycle as the next set of goals is established. These final phases of the cycle – implementation / reflection / debrief – should feel less like a final performance and more like a catalyst for further study and improvement of practice (Lewis *et al*., 2006b).

Lesson study is a straightforward idea, but a complex process, requiring the commitment of teacher participants over a long period of time and an openness to learn about subject matter and its teaching and learning (Lewis *et al*., 2006b). According to Lynn Liptak, a principal involved in lesson study in the United States, "anybody who goes into lesson study because they want a quick fix is going to be disappointed. This is not quick. This is a long-term strategy" (Richardson, 2001). That being said, teachers such as the one cited below have commented about the rewards of lesson study (Fernandez, 2002):

> In my experience lesson study is the most important thing for me to improve my teaching method or teaching techniques. Many teachers have observed me during my lessons and I have asked them to give me comments and criticize my lessons ... Through these experiences, I believe that my teaching method has improved.

2.3 Ideal Conditions of Lesson Study

According to the Psychology of Mathematics Educators of North America (PMENA) lesson study working group, there are five ideal conditions that contribute to success in lesson study: the presence of outside experts; a supportive and present administrator; the development of trust; the ability to experience and discuss 'what makes a good math lesson'; and the identification of an area of mathematics teaching / learning that is problematic (Bruce, 2007). A brief discussion on the first two conditions is outlined here.

An outside expert is considered to be a person who works externally from the group (e.g., a university participant researcher). This outside expert may be a content expert, who asks probing questions and facilitates teacher interaction with one another (e.g., asking "how can we link geometric and algebraic representations in this task?"), assisting with unpacking of the lesson/task, discussing how to support individual students through *planful* differentiated instruction. This type of outside expert is common in Japan and is gaining popularity in North American lesson study projects. Another role of the outside expert is to facilitate the lesson study process. As a teacher participant said "It would be very difficult to transform the way your school does professional development without 'knowledgeable others'" (Jarrett Weeks, 2001). In these cases where the outside expert acts as facilitator, there is, ideally, a gradual release of responsibility to the group as a teacher leader takes over the facilitation role.

The PMENA working group considered the lesson study situation ideal when a lesson study teacher team is supported by an administrator who is involved from the beginning stages and continues to be a presence throughout the lesson study cycle. Researchers have consistently established a positive relationship between effective principal leadership behaviours and student achievement. Without effective leadership, even staffs with many dedicated and skilled teachers are not able to function as an effective school community to ensure high levels of learning. One school administrator describes the role as non-traditional: "You are not leading from in front (where you have the answer and share it). You are not leading from behind (where you facilitate). You are truly leading from within along with everyone else" (Liptak as cited in Boss, 2001). The administrator is also in a position to be able to use lesson study in order to respond to external mandates so that "lesson study is not one more demand on teachers but the primary means of addressing the many demands they face" (Lewis *et al*., 2006b).

2.4 Demonstration Classrooms

Demonstration classrooms constitute a professional learning strategy in which teachers visit a model implementation site to learn how to implement innovative instructional practice. Although models may differ and include additional features, at its most basic, a demonstration classroom visit involves:

1.) A pre-conference, during which participating teachers meet with the host teacher to discuss learning goals, issues around planning and assessment, anticipated student responses, and other issues of interest to the host or visiting teachers. At this time, visitors may discuss and take on observation roles for the classroom visit, depending on the learning objectives of the lesson and of the teachers themselves;

2.) Teachers then attend the demonstration lesson, taking careful notes on student responses and interactions, teacher decision-making, features of the classroom or of the lesson. Observation guides, tailored to the goals of the demonstration classroom, may also be used;

3.) Visitors meet with the host for a post-lesson debrief, during which observations are shared and implications discussed;

4.) Participating teachers set goals for implementation in their own classroom. Immediately following the demonstration classroom visit, teachers may be afforded release time in which to pursue these goals through further research, co-planning, etc.

Demonstration classrooms may be particularly effective when teachers have difficulty imaging what an innovation would like in practice.

Few studies of the effects of demonstration classrooms on teachers and students have been reported and the limited body of literature that does exist appears to focus on disciplines other than mathematics. A few studies are worthy of note in the literature. Pinnell (1988) found that observing a lesson enabled teachers to change their perspective of students, provided them with concrete examples for reflection and increased their understanding of theories underlying instructional decisions. Pinnell also found that the teachers' sense of responsibility for student learning increased. Putnam (1985) examined the benefits and limitations of different types of demonstration lessons and found that they were perceived as beneficial if they were live (rather than videotaped) and showed teacher decision making. Putnam and Johns (1987) found that demonstrations were valuable to teachers if they stressed the connection between theory and practice.

Luft (1998a; 1998b; 2001; Luft & Pizzini, 1998) is worthy of a more in-depth discussion. She studied the demonstration classroom model extensively in the context of the

American middle and high school science classroom. The comparison of science reform and math reform provides an interesting parallel, and may be of assistance in understanding the function of math demonstration classrooms for several reasons. Science education has gone through reforms similar to the reform standards that have been applied to math in the past two decades; these reforms, like the reforms in mathematics education, re-envisage science as a process of inquiry. As such, the National Science Education Standards hold that science instruction should be student-directed, emphasize scientific and critical thinking skills, as well as collaborative group work (National Research Council, 1996, cited by Luft, 1998a). Luft points to research that shows that many elementary teachers feel unprepared to adequately teach science (George et al, 1996; Suter, 1993 cited by Luft, 1998b): a similar phenomenon occurs in math. Luft's work is primarily involved with helping teachers to develop extended inquiry and problem-solving approaches in their science teaching. This problem-solving approach in science instruction and the challenges that teachers face in implementation are helpful to understanding the challenges that math teachers face in enacting the three-part lesson.

One study (Luft & Pizzini, 1998) focused on student change as a result of the teachers' participation in the demonstration classroom in-service program. The time spent in cooperative learning groups, the cohesiveness of the groups, the participation of students, the role of the teacher, and the opportunity for student-directed inquiry were all found to have increased significantly. Researchers attributed these changes to the observation and dialogue involved in the demonstration classroom process, which allow teachers the opportunity to socially construct knowledge. These results are consistent with the literature on teacher change (Luft & Pizzini, 1998). The researchers also distinguished the types of changes that teachers made and found that instructional changes (relating, for example, to changes in planning, in the amount of time provided for group work within the lesson and in the structuring of the lesson to increase student participation) were readily made, while personal changes involving the behaviours and beliefs of the teachers did not occur as completely.

In Luft's series of studies on demonstration classrooms, the in-service program was progressively refined, with features being successively added to further support the participating teachers in their learning and implementation. The initial conceptualization and development of the demonstration in-service program was critically informed by the literature and research on effective in-service practice, peer-centred practices, and clinical supervision. The program initially consisted of traditional in-service workshops (over four days in the summer, which included some time for planning) supplemented with visits to classrooms enacting inquiry-based science lessons. During the year, participants were encouraged to implement the problem-solving model in their classrooms, especially prior to the visits to the demonstration classroom, so that areas that required clarification could be addressed during the visit. Copies of handouts, overheads and other materials were given to the teachers at the lesson. Participants also received feedback about their own implementation following observations by university science educators or district staff development specialists. In a later study (Luft, 1998), participants were encouraged and mechanisms were provided to observe one another. Electronic forums also provided a way for participants to share ideas. In yet a later study (Luft, 2001), moderated electronic discussions were added in addition to added opportunities for the participants to visit one another and the demonstration classroom teacher. According to Luft, this refined model attends to the principles of effective professional development because it addresses the specific needs of adult learners, provides ample opportunities for follow up and reflection, and utilizes models and methods that represent sound pedagogy as well as content.

3. METHOD

3.1 KPR GAINS Research Design 2008-09

The KPR GAINS research study for 2008-09 was designed to look closely at the effects, including merits and challenges, of two different professional development strategies for mathematics teachers. The two PD models are Lesson Study (LS) and Demonstration Classrooms (DC). The treatments ran simultaneously within the Kawartha Pine Ridge District School Board.

The study employed a mixed methods design in which quantitative and qualitative methods were conducted independently. Research questions were addressed through quantitative and qualitative approaches with the goal of triangulating the findings and using each methodology to illuminate the other (Creswell & Plano-Clark, 2007).

3.2 Research Questions

1. What are the effects of the two treatments on teachers' professional beliefs, knowledge of mathematics teaching, and instructional practices?

2. In which circumstances would it be effective to apply a Demonstration Classroom PD program and in which circumstances would it be effective to apply a Lesson Study PD model?

3.3 Qualitative Case Studies

In order to gain rich insights into the merits and challenges of each treatment program, we conducted one intensive case study for each treatment.

3.3.1 Demonstration Classrooms Participants and Data Sources

There were 3 demonstration classrooms in the district at the onset of the project, with 1 site closing due to a change in personnel (a demonstration classroom teacher became a district level coach). This was a new model of professional learning that the district was interested in implementing. The local consultant for mathematics facilitated this aspect of the project. For demonstration classroom experiences, one school team who participated in visits to a demonstration classroom, was selected based on voluntary agreement of the teacher members and administrator(s). Activities related to demonstration classroom activity included: facilitating teams in setting goals, organizing demonstration classroom visits, setting goals post visit, establishing an implementation plan. Visiting teachers were provided with 2 days of release time for observation, discussions and planning sessions.

Data collection for the demonstration classroom case study involved:
a) video documentation of team meetings through all stages of the demonstration classroom process;
b) classroom observations (consistent observation guide);
c) interviews with team members and administrator(s).

3.3.2 Lesson Study Participants and Data Sources

For lesson study, there were 4 participating schools. One school team was selected based on voluntary agreement of the teacher members and administrator(s). Although one case study was in focus, all lesson study teams required facilitation through the process and were fully documented. Some teams and/or teachers on teams had already experienced two cycles of lesson study (in a previous academic year of research) while others had never experienced lesson study. Ways to facilitate bringing the new teams and teachers on board included: having an experienced lesson study participant on site whenever possible; cross-team facilitation by pairing lead members of the experienced teams with lead members of the non-experienced teachers; having access to math education instructors and researchers regularly.

The lesson study sample consisted of three teams from the 07-08 project that asked to continue in 08-09 with added members for each team for this second year. This created new, larger teams with an emphasis on cross-divisional groupings:

Team A (one school): 4 teachers - one primary, one junior, two intermediate
Team B (two schools adjoined): 5 teachers - two intermediate, three secondary
Team C (two neighbouring schools): 4 teachers - two junior, two secondary

Each lesson study teacher received six supply days for planning and implementation purposes.

Data collection for all the lesson study school teams, including the case study involved:
a) regular field notes at team meetings through all stages of the lesson study process;
b) video documentation of the lesson study process including public lesson documentation;
c) electronic collection of lesson and goal setting materials developed by the team;
c) reviewing of public lesson with commentary from team members;
d) interviews with team members and administrator(s);
e) classroom observations (consistent observation guide).

See Appendix A for a comprehensive listing of the qualitative data sources from 2008-2009.

3.4 Qualitative Data Analysis

In the first level of qualitative analysis, for the two case studies (one in DC, one in LS), three researchers collaboratively generated start codes that were common to the two cases. Researchers then electronically formatted and coded data using the start codes (see Appendix B). Researchers then independently coded selected sets of data, and compared analyses. The codes were modified and modestly expanded, then all data were coded by two independent researchers in order to ensure triangulation. Code counts (for intensity and frequency) and lengths of iterations then helped determine the driving themes (axial codes) of the cases. Subsequently, the remaining lesson study data sets from the non-case study schools were coded using the same coding matrix.

During the early analysis stages, researchers also generated two diagrams for testing: one for DC and one for LS (see Figures 2 and 3). Researchers compared hypothesized events to the actual data summaries (pattern matching: Mark, Henry, & Julnes, 2000). Figure 2 was generated at the end of Year One of the lesson study initiative, based on focus group discussions with participants. Figure 3 is purely theoretical.

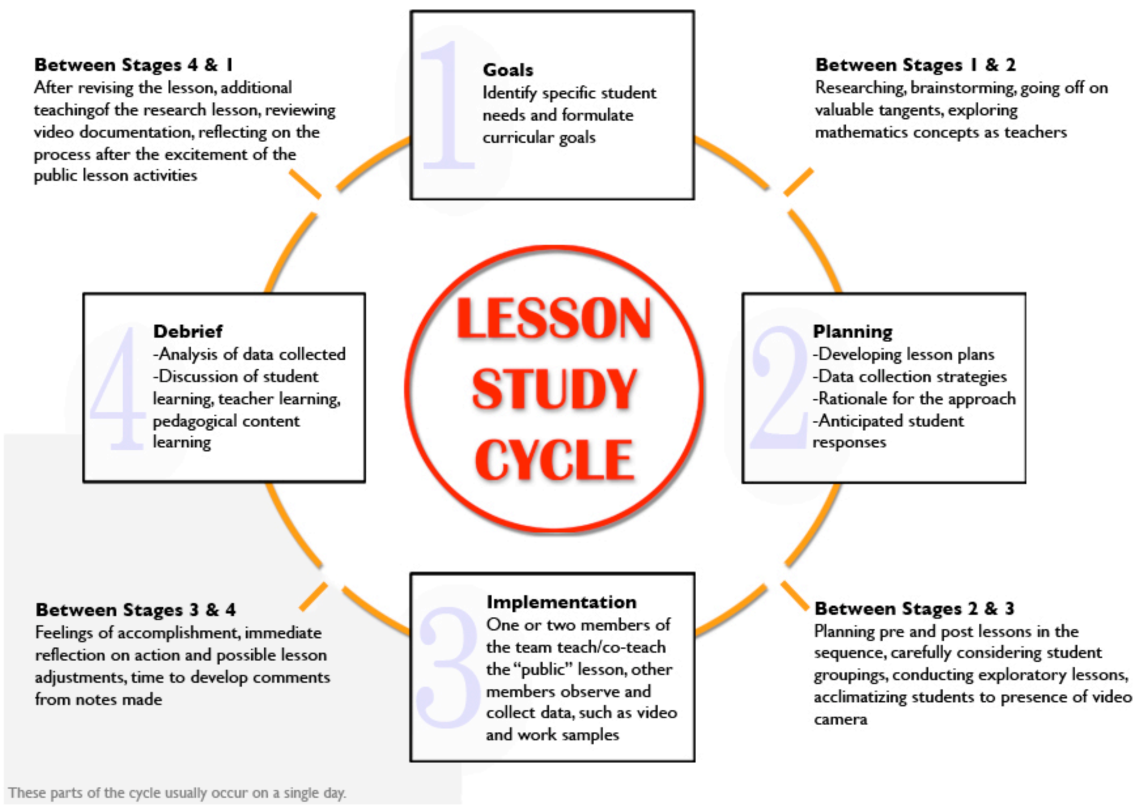

Figure 2. *Lesson Study Model Tested*

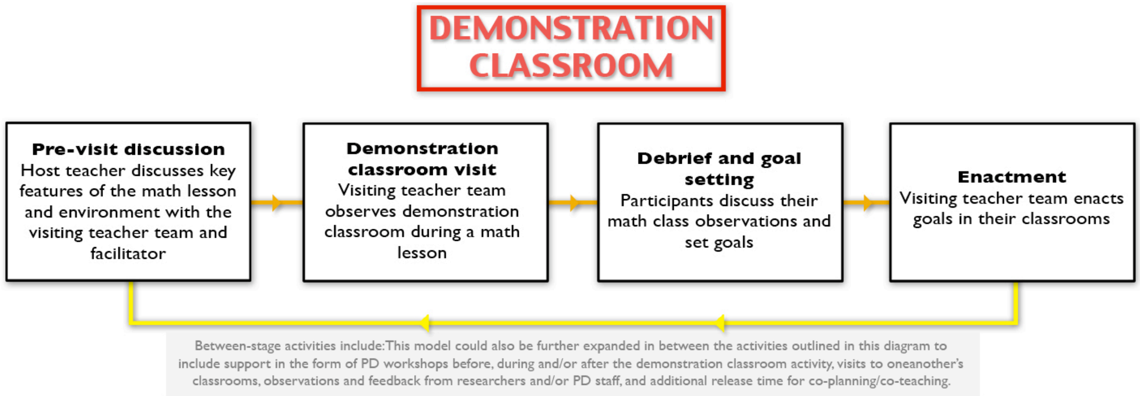

Figure 3. *Demonstration Classroom Model Tested*

Once all data were coded and tested against hypothesized events, researchers developed the case studies into two parallel research stories:

1. These stories were developed in standard written research form for this report.
2. The stories of lesson study and demonstration classroom were developed in the form of electronic Digital Papers (see Appendix C for full explanation of a Digital Paper). Digital papers are web-based interactive and research-based forms of communication that attempt to facilitate practitioner professional development. Video segments directly from the research data sets were selected for use in the Digital Papers. These video segments were carefully selected and transcribed because they illustrate the PD models "in action".

3.5 Quantitative Method

We conducted a mixed methods study in which the main data collection was qualitative. Quantitative methods were used to inform the qualitative findings and triangulate with the case study results. There was no true control group; rather there were two treatments provided to dissimilar populations. We analyzed and reported the data separately for each treatment.

Teachers completed surveys at the beginning and end of the study. The surveys measured teachers' self-reported teaching practices (a high score indicated support for Standards-based mathematics teaching), three measures of math teacher efficacy (confidence in engaging students, delivering instruction, and managing students in math class), as well as teacher background in mathematics and math education. At the end of the project teachers reported their experiences in lesson study or demonstration classrooms and responded to items probing the extent to which they had created a Math Talk Community in their classrooms.

Student achievement measures were piloted during the study and require further field testing.

4. FINDINGS

4.1 Qualitative results for demonstration classroom

<u>Case Study: Oriole Park School</u>

4.1.1 Background

a) School Context

Oriole Park Public School is a JK-6 school with an enrollment of 340 students. The school faces some academic challenges. The EQAO results for Grade 3 for 2007-2008 indicate scores that were lower than the provincial averages for reading, writing and math. The data from the math portion of EQAO indicate that over 30% of students are achieving level 3 (compared with 68% provincially), and represents a drop of achievement over the 3 years prior to 2007-2008.

The results for Grade 6 EQAO tests show results in reading and writing that are hovering near the provincial averages and show growth over the past 3 years (up 21 and 36 percentage points respectively). EQAO results in math are less positive, with less than 10% of students achieving level 3 or better, compared to the provincial average of 61%. This also represents a drop over the past 3 years.

In addition to academic challenges, the students at Oriole Park School face significant socio-economic challenges, with over 35% classified as living in lower-income households (compared to a provincial average of 16.5%). Other significant indicators show that only 13% of students at Oriole Park School have parents who have some university education, compared to 36.9% provincially (School Information Finder). The school has been flagged as a high needs school both at the district level and provincially.

b) Background of the teachers

Sean is a Grade 6 teacher. He has been teaching for seventeen years. He has taught Grade 6 for the past eleven years, having taught Grades 2 and 3 prior to that. He describes his strengths as language and visual arts, and describes math as a "weakness" (May interview).

Sarah has taught Grade 5 for the past eight of her eleven-year teaching career. She describes herself as a the kind of math student who could "follow the steps, but without understanding why" (June interview). She stopped taking math in high school when this conceptual deficit made it difficult to go on to higher order math courses.

There is a sense of rapport between the two teachers. They express deep mutual professional respect and in interviews discuss similar philosophies of teaching, involving the importance of establishing a sense of community in the classroom, embracing the diversity of their students, and taking risks in trying new things in teaching. They have worked collaboratively in the past, as part of a math-coaching project several years ago. This is the first occasion they have had since that time to work together collaboratively in a structured format.

4.1.2 Team Implementation

Their principal approached the teachers about attending the demonstration classroom, and the teachers agreed because they were interested in gaining new insights for their math programs. The following table outlines their activities:

Table 1
Demonstration Classroom Events Schedule

Date	*Event*	*Description of Activity*
February, 2009	Visit to demonstration classroom (teachers and principal)	1st visit to the demonstration classroom (preceded by a ½ hour meeting with the host teacher and PD consultant from the board, with a debriefing session to follow, and a half day release back at the participants' school for further investigation and planning)
May 6, 2009	Interview	Researcher interviewed the teacher participants
May 14, 2009	Classroom observation	Teachers planned 3-part lessons to enact in their classrooms (videotaped)
May 20, 2009	Visit to demonstration classroom (Principal and researchers also attended)	2nd visit to demonstration classroom (same format as the first visit: short meeting with the host teacher beforehand, a debriefing session afterwards, and a ½ day of release for planning)
June 16, 2009	Classroom observation	Teachers planned 3-part lessons to enact in their classrooms (videotaped)
June 16, 2009	Interview	Researcher interviewed the teacher participants, and the administrator

4.1.3 Findings

a) Teacher Learning

The teachers reflected on their learning in the demonstration classroom during the interviews that followed the first and second visits to the host classroom. Several important themes emerged.

The Value of Observation

The central feature of the demonstration classroom – observation – was the key catalyst for teacher learning: "The greatest PD, I think, is visiting each other's classrooms. And listening to each other talk about our practice" (May interview). The power of seeing the lesson enacted, rather than reading about it or being told about it, was repeated several times according to code counts. Both teachers had spoken about not having had many opportunities to observe other teachers teaching, and about the power of having that opportunity. One teacher described the chance to observe as a luxury: "To have the luxury of watching someone else do that and unpack their thinking is fantastic because then you see it does loop back to you and you think, okay, in juxtaposition, what do I look like" (May interview)? The teachers valued that what they witnessed in the observation wasn't a polished piece, but a "piece in process" and that they had an opportunity to see the demonstration classroom teacher taking the risk of trying new things and learning in the process (May interview).

The value of the observation lay not just in seeing the teacher, but in observing the students. Sarah expressed what many teachers think when learning about new teaching strategies in PD workshops:

> When we go to a lot of these PD things we always think, oh yeah, it works with those kids but not our kids. So if we were to do this thing where we are sharing and opening up our classrooms, then people can see that there are possibilities with the kids that we teach and the resources we have. (June interview)

Sean added that the polished presentations that are given in most PD contexts are "far removed from our experience."

The visit to the demonstration classroom placed the learning within the context of the classroom and made it recognizable and accessible to teachers. Even though the three-part lesson was familiar to the teachers, seeing it enacted led to new observations and understandings of how it could work, what it could look like and sound like, in their classrooms with their students. In the analysis of the qualitative data, the idea of seeing the three-part lesson emerged as a powerful theme and a driver for the teachers' inquiry and learning. After the first visit to the demonstration classroom, Sean spoke about how the 3 stages of the three-part lesson – minds-on or activation, development and consolidation – were hard to visualize. He described being unclear as to what these stages would look like in the context of his classroom. This difficulty in visualizing the complexities of the three-part lesson is what ultimately motivated him to take part in the demonstration classroom project. As he put it, "when this idea came up, to see somebody who was doing it [the three-part lesson], I thought, okay, because I like to see stuff, I don't like to read about it only" (May interview).

Later, one teacher explained how the demonstration classroom would provide "a great way to actually see it. I could read about it but I don't have much time at home for that kind of research, but to see it being done was more meaningful for me" (May interview). Following the second visit to the demonstration classroom, Sarah confirmed:

> It's not enough just to hear about a lesson or plan and just think about how it's going to help you and what you could do with it. For me to actually see it being done and how it's working, how it's not working, and what I could do with it so that it suits me and my students at my school. That for me was the benefit. (June interview)

The grounded nature of the learning left the teachers excited to plan some three-part lessons. They reported that when they returned to the school after the first visit, they set right to research and planning. Sarah described how, while Sean did additional research on the three-part lesson and resources, including the textbook, she "did more of the thinking and planning on what I could do right now, what can I take away from that visit." Sean described how he "started to write lessons around … the 3-part lesson, but I changed the names of the sections…and since then, I've been writing lessons that use the 3-part piece, but not every single lesson." Sarah too was planning some three-part lessons around what she had seen in the demonstration classroom.

Strategies for achieving consolidation

Also, the fact that they were able to actually see the lesson in the authentic setting of the classroom allowed teachers to immediately implement some practical strategies to support the implementation of the three-part lesson format in their own classroom. For example, during the first visit to the demonstration classroom, teachers were immediately struck by the organization of the classroom. Sarah noted that different areas of the room were used strategically for different purposes: "not just display purposes, but actually where she would teach or where the kids could go" (May interview). Later in the project, Sarah reflected:

> I think for me it's been more of a heads up to attempt to do the three-part lesson as often as I can and when it fits. And for me one thing I had to do is set up reminders. So I have changed where I teach math, physically in the room, and that reminds me to do the activation piece and then I also change spots for when we consolidate. So just physically changing the room like that has given me just kind of a cue too, okay, yeah, I'm supposed to do this now. And I'm finding that I'm doing it more often and that it's valuable to me.

Earlier these organization details had not been tied to the math, but now they were directly tied to math and the enactment of the 3-part lesson. The physical spaces connected to the lesson structure enabled Sarah to cue herself to maintain the structured format she was learning to implement.

Another practical strategy enacted as a result of the visit involved Sarah purchasing a timer for the room (something she had seen used in the demonstration lesson). She reported using it to help her track time so that she wouldn't run out of time for consolidation at the end of the lesson, which both teachers acknowledged was a critical stage that was often abandoned due to 'running out of time' (May interview).

Resources for problem-based learning

In the meeting before and after the demonstration lesson, the host teacher told the visitors that her focus was not to use the textbook and that "she was able to do that for a couple of months, and then she had to look into it for ideas, and use it in her classes" (May interview). The reluctance the demonstration teacher had in relying on the textbook as a source of rich tasks is reflective of a perception that rich problems must be found elsewhere or created from scratch by the teacher, adding significantly to the amount of time involved in planning, but lending to the genuine fit of the tasks selected and/or developed with students in the class.

The teachers reflected on the demonstration classroom teacher's use of the textbook and revised their thinking about textbook use: "So I thought about that, and actually when we were done the visit, we talked about how we could actually use the book within the framework of the 3-part lesson. We found some connections and some things that we could do" (May interview). Later the teachers added, "and we've talked about using the text exclusively [as a resource for the 3-part lesson planning], and it does work, you can make it fit (May interview). This is an important realization with implications for other teachers learning to implement the three-part lesson. Knowing that the textbook can remain as a valuable math resource even in a problem-based math classroom may help some teachers to overcome the long-declared 'barrier' of finding resources that support a problem-solving approach to math teaching.

Asset-oriented approach to differentiation

In the first demonstration classroom visit, the teacher used a layered task with multiple entry points for students. This in itself was not a new idea for the teachers, but rather, it was the *way* that the task was layered and how students could find entry points and then move through the task that affected powerful learning for one teacher.

Sean described what he saw in the class:

> Then she had them layered up in terms of complexity. And so the kids would get a whole package and they could go in at any entry point and move through these layers. Some would stop at the first layer because that was where they were maxed out… I'd never thought of that before. It just made so much sense. Instead of looking at it in terms of, for DI [differentiated instruction], you've got this child who's on a Grade 4 IEP, so you're going to take the same lesson and you're downgrading it. Instead of that, no, you go in with the big learning, and then just open it out so that it actually goes from where you want it to *up*, instead of from where you want it to, *down*.

This idea of designing lessons based on the "big idea" and scaffolding up, rather than creating simplified parallel tasks for lower students, was important to the observing teachers, who later reflected that this approach would help them with ongoing formative assessment as they could monitor which layers individuals were able to access, and even more powerfully, would help them to reach every student and support conceptual understanding of the "big ideas."

Strategic groupings

Teachers observed that the groups the demonstration classroom teacher had established for group work were dynamic and changing. The host teacher had explained that she changed the groupings constantly, based on the learning goals for that day and assessed student understanding up to that point, meaning that students who needed support in particular learning goals or who had gaps were grouped together to work towards that goal. For example, one small group of students was continuing to struggle with comparing fractions with unlike denominators. This was impacting their ability to solve some of the measurement problems the class was solving. The teacher had this group of students working on comparing fractions while other groups worked on different problems involving ratios. One observing teacher explained: "I like the dynamic groupings piece, where it's not ability based, it's just needs based. I really like that a lot, that basically deals with the reality of the classroom much more efficiently" (May interview).

Teacher learning about Math Communication

Following the second visit to the demonstration classroom, Sean had set a goal of enacting a 3-part lesson. He was very familiar with the structure of the 3-part lesson, but had consistently found that he ran out of time for consolidation at the end. This was a specific goal that he articulated in the debriefing following the May visit to the demonstration classroom: to do a 3-part lesson that involved group work and elicited rich student communication, and in which a purposeful consolidation was achieved. In June, he enacted the lesson with his class in the presence of a researcher and the video camera. He carefully planned the lesson, which involved a brief activation, a development, and a consolidation in which students could share their findings. Students were presented with a problem in the development part of the lesson that required them to build a growing pattern to help them choose which prize they would rather receive: 250 gifts on the first day, or a growing number of gifts on each subsequent day. To Sean's surprise, his usually talkative classroom was nearly silent during the problem solving. When reflecting on the lesson Sean said:

> But I did feel good about today. I really felt like I moved. I really consciously thought about that, how I was going to get them engaged and activate their prior knowledge and I really thought about that a lot. I was pretty excited about it actually, I was. But I don't want it at the expense of their talking. That was such a huge loss, honestly, I've not seen that before. I just don't know where it went. (June interview)

Students had been given little direction in terms of strategies for solving the problem, and it was expected that there would be some collaboration and discussion, which was a norm in the room. Instead, there was very little discussion at all. Sean found this surprising and it was a major point of focus in the interview with the researcher that followed. He wondered if EQAO and other testing in recent weeks, which involved highly structured and individualized testing situations, had affected students. He further wondered if the silence of the students was connected to his planning; he described a generally looser structure to his lessons, and wondered if the very structured nature of the lesson had given the students the impression that their work was also to be highly structured. He reflected on finding a balance that would allow him to retain some flexibility in responding to the learning and teaching moment: "For me, it's the highest form of teaching, to take a concept and right in that moment not have it pre-unpacked but unpack it *with* the kids. That's pretty powerful learning. So I learned from [the host teacher] a lot about that, about the courage of that" (June interview).

In spite of the unanticipated student silence, Sean reflected positively about his attempt to achieve the goal of enacting consolidation within the framework of the 3-part lesson, which he felt he had succeeded in doing. In assessing the overall 3-part lesson, Sean stated: "But if you wanted to just take the framework, I felt it was successful, I felt like at this point that was my best rendition of it to this point. But it's still not where I want it to go" (June interview).

Even though it proved to be challenging and had unanticipated results, this teacher was setting high standards for what he wanted to see in his classroom, and this experience planted a seed for continued pursuit of the three-part lesson and strategies to foster effective math communication for students.

b) Teacher Collaboration

Collaboration of the Observing Pair of Teachers

Teacher collaboration emerged as a most powerful theme in the teacher interviews. There was evidence that the demonstration classroom experience provided new avenues for professional dialogue amongst the participating teachers. When the teachers returned to their schools from the first demonstration lesson, they had a half-day release time with which to pursue some planning goals based on what they saw and learned during the demonstration classroom visit. Sarah described their activities upon return to the school: "when we came back, it really got Sean and I talking about what we saw, what we could do, what we can plan on doing" (May interview). Sean added that "it had been a while" since they had engaged in a professional dialogue. He explained: "we talk all the time, but we don't necessarily talk specifically about strategies you can use to frame your teaching or your thinking or your children's learning" (May interview). When they got back to the school, they reported talking about what they had seen and what it might look like in their own practice and began taking practical steps towards implementation, like looking for resources and planning lessons.

Dialogue Beyond the Observing Pair

Interestingly, the dialogue spilled over to other staff members who weren't involved in the demonstration classroom project:

> And for the record here, when we did come back, we didn't start just talking amongst ourselves, but with other teachers, and we found out some teachers have been doing the three-part lesson plan, and we shared resources. So that was really interesting to see, because had it not been for the project, we wouldn't have known that. (May interview)

The participating teachers' visit to the demonstration classroom sparked curiosity amongst the rest of the staff and the teachers reported that several people had asked if they could come in and observe what they were doing in their classrooms as a result of the visit. The teachers reiterated several times that they had, through these discussions and as a result of the demonstration classroom project, learned of other teachers working on similar goals relating to the three-part lesson. One teacher put it this way: "One of the things that we realized, and we've always known it but it's just never been laid bare, it is that we have a lot of people who are trying things out in their rooms" (June interview). This experience, then, resulted in some dialogue amongst staff members that the teachers thought was leading towards more professional collaboration, in the form of PLC meetings and observations in one another's classrooms, with the potential to affect the culture of collaboration in mathematics in the school: "Had we not taken this up, I don't think we would have known about the other staff members who are doing it. So we now have another resource for us to go and talk to and see what's working, what isn't" (June interview). The participating teachers saw this as the start of a dialogue that would continue.

c) Teacher renewal

Sean described being unhappy about his math planning prior to the demonstration classroom project. He indicated that he may not have had direction or goals for channeling improvement efforts:

> I had no planned model in terms of, here is how I'm going to engage them, nothing. I had nothing. And it was showing up. Because I wasn't happy and I knew the kids weren't learning as well as they could. And that's why this has been really really important to me. Because it's made me rethink and really focus in on, how can I make math meaningful to my kids, engaging for me to teach and assessable as well? Accessible and assessable. And so that's been huge. (June interview)

He further described what was most beneficial to him about this form of professional development:

> …being actively involved in something and seeing a person risk-take, coming back, having a dialogue with a colleague about something that I really value – and I have to work harder at math than anything else because it doesn't come easily to me – and being able to talk to my colleague and hearing and seeing her work and the excitement and the realities of teaching it – both. And then to hear that my other colleagues were equally excited for us and that we could bring something of value into their lives and that they had stuff that we could use too….We all have great stuff. And to have that whole piece start to emerge

> again has been really powerful. And the fact that my kids are able to do things now that I really value that I know they couldn't have, in part because of this work, is something that is more important to me than any of the rest. Because it's another tool to give them back their right to think. (June interview)

These comments underscore the potential of professional collaboration in teaching, especially through the process of observing someone teach and engaging in professional dialogue about that shared experience.

d) Nature of Math Communication

Sarah and Sean had already been working on math communication in their classrooms prior to their participation in the demonstration classroom project. Because of the high level of math talk implementation already in place, this was not an area of need and therefore not a focus for their demonstration classroom visits. Nevertheless, observations about the nature of math communication in both classrooms were made during the May and June visits by researchers.

Mathematics communication was an evident strength in both teachers' classrooms. Both had posted the math talk guidelines (Bruce, 2007) as anchor charts that were clearly visible to students. In Sean's room, students were evidently comfortable with the guidelines, using "I agree because" and "I disagree because" with some teacher prompting; for example, Sean would regularly invite students to "agree, disagree, build on" in response to a peer in a whole group prompt, and students would take up this invitation readily. In interviews, Sean articulated his goal for further refinement of math talk in his classroom; he wanted to encourage students to talk and respond directly to one another rather than through the teacher. He scaffolded this by encouraging students to turn and look at one another while agreeing, disagreeing or building on. By prioritizing student-student communication, Sean demonstrated a high degree of comfort with the math communication already happening in his classroom and with his role as teacher-facilitator. He was working on turning the responsibility and accountability for the communication over to students, which demonstrates a high-level refinement to the focus of math communication in his classroom.

In Sarah's room, students were also very comfortable with using the math discourse guidelines to communicate their mathematical thinking to one another. Students were observed using the guidelines, unprompted, in whole and small group situations. In one consolidation, during which Sarah had the entire class move their chairs to form a large circle in the middle of the room, students were observed communicating directly with one another, with very little teacher moderation. For example, students were observed saying, "I like what you said, but I saw it another way," and "I disagree with what you said, Jordan…" (video episode, May). In these instances, the teacher was not the sole point of reference. Sarah's goal for math communication was to get students using precise mathematical terms as part of high quality math communication. Some strategies that were observed included the use of a math word wall, a Jeopardy game that focused on the math terminology relating to the learning goals of the day, and modelling the use of precise terminology.

4.2 Quantitative Results for Demonstration Classrooms

The case study data showing positive effects of participation in the demonstration classroom treatment on teacher outcomes were confirmed by the quantitative results. We conducted a series of repeated measures analysis using pre- and posttest scores for each of the teacher outcomes. Table 2 displays the pre and posttest means and standard deviations, the results of the repeated measures analysis of variance, and the effect size (Cohen's *d*). There were improvements in all the teacher outcomes but only two were large enough to be statistically significant findings: teachers in the demonstration classroom treatment reported that they were more collaborative after participating in the in-service than they were before and their self-reported use of Standards-based mathematics teaching increased. The first of these differences was small; the second was large.

Table 2
Effect of Treatment on Teacher Beliefs and Teaching Practices for Demonstration Classroom Teachers (N=14)

Teacher Outcome	Pre Mean	Pre SD	Post Mean	Post SD	GLM Results	ES
Math teaching practices	4.61	.44	4.73	.41	$F(1,13)=17.43$, $p<.001$	.28
Collaboration	3.96	.57	4.50	.42	$F(1,13)=20.91$, $p<.001$	1.08
TE: student engagement	3.86	.74	3.71	.60	$F(1,13)=1.43$, $p=.252$	.21
TE: instructional strategies	3.82	.69	3.96	.59	$F(1,13)=1.507$, $p=.241$	.22
TE: classroom management	4.21	.63	4.32	.43	$F(1,13)=.527$, $p=.481$	.20

TE=Teacher Efficacy

In summary, the quantitative data confirm the case study findings that the classroom demonstration in-service contributed to teacher's knowledge, beliefs, and self-reported practices, with particularly strong effects on teacher collaboration. All of these teacher outcomes were positive.

4.3 Qualitative results for lesson study

<u>Case Study: Hillside School</u>

4.3.1 Background

a) School Context

Hillside is a K-8 school located in an urban area of a town of about 75,000 people in central-Eastern Ontario. Its school population of 264 students face significant socio-economic challenges. The school has a higher percentage of students living in lower-income households compared to the provincial average (22% percent, compared to 16.5% provincially, according to the Ontario Ministry of Education's school profile). Only 19% of Hillside's students have parents who have some university education, significantly lower than the provincial average of 36.9%.

Hillside's math and reading scores in the Grade 3 provincial assessments (EQAO) are on par with the provincial averages, with just less than 60% of students achieving the provincial standard in writing (compared to 61% provincially), and 70% in writing (compared to 66% provincially). Reading and writing scores suggest a strong upward trend for student achievement, with 31- and 56-point increases respectively over the past 3 years. Math scores in Grade 3 tell a similar story, with 63% of students achieving the provincial standard (a 29-point jump over 3 years).

Student achievement scores in Grade 6 are consistent in reading and writing, hovering near the provincial average at 65%. The Grade 6 math scores tell a different story, however, with just over 30% of students achieving the standard compared to 61% provincially – a 24-point drop over the past 3 years (School Information Finder, 2009).

In spite of its challenges, the atmosphere at Hillside is a pleasant, welcoming place. A high level of energy and commitment is evident among the staff. The principal is active and highly visible in the school. There is cheerful banter in the hallways and in the staff room. Aside from lesson study, collaborative professional development has been taking place in the school in the form of divisional, mandated Professional Learning Communities (PLCs), for which teachers meet in their divisions to establish short-term targets for student achievement, mostly in literacy.

b) Background of the Teachers

In the first year of the study, the team of three teachers focused on understanding lesson study and developing their understanding of effective uses of the interactive whiteboard in the math classroom. In that year, the team consisted of two Grade 7/8 teachers (representing the entire intermediate division) and one Grade 4 teacher.

In this second year of the project, the team expanded to include a primary teacher from their staff (so that each division was represented) and to develop some exploratory lessons in their focus area. These exploratory lessons allowed the teachers to really develop their understanding of student learning in content areas across the divisions; for example, the team developed a problem which they implemented, with only minor variances, in Grades 1, 4, 7 and 8.

4.3.2 Team Implementation

a) Areas of teacher team emphasis (goals)

The teachers had been careful to choose a focus area – communication – that was broad enough to allow them to do this kind of cross-divisional planning and experimentation. Specifically, their goal was to facilitate effective student communication in mathematics with the use tools and technology, including manipulatives as well as the interactive whiteboard (IWB).

As a secondary goal, the lesson study team wanted to invite other teachers in the school to become involved in lesson study through collaborative lesson planning in divisions, implementation of "exploratory lessons" (lessons that explore what students are capable of in a specific math content area such as comparing fractions with unlike denominators, and that assist in determining how to refine the public lesson), and observations of exploratory and public lessons.

b) Teacher team activity

The teacher team ran through two cycles of lesson study over the course of the 2008-2009 school year. They received addition release time funding through a provincial collaborative action research project. The first public lesson took place in a Grade 7/8 classroom in November, 2008 and the second public lesson took place in a Grade 1 classroom in May, 2009. These events as well as other lesson study-related activities of the team are outlined in the following table:

Table 3
Lesson Study Events Schedule

Date	Event	Description of Activity
October 3, 2008	Planning meeting (1/2 day)	Goal setting
October 16, 2008	Planning meeting (1/2 day)	To develop student measures
October 23, 2008	Planning meeting (full day)	To plan exploratory and public lessons
November 4, 2008	Exploratory lesson	In Grade 4 class, other teachers attending
November 21, 2008	Planning meeting (1/2 day)	To plan public lesson
November 26, 2008	Public lesson (1/2 day) and planning meeting (1/2 day)	Researchers and several staff members and other members of educational community present for public lesson
January 15, 2009	Planning meeting (1/2 day)	To reconnect with goals and start planning for 2nd cycle of lesson study
February 18, 2009	Planning meeting (1/2 day)	Planning for exploratory/public lesson
March 24, 2009	Planning meeting (full day)	Planning for exploratory/public lesson
April 28, 2009	Planning meeting (1/2 day)	Planning for exploratory/public lesson
May 1, 2009	Public lesson (1/2 day), and meeting (1/2 day)	Researchers and several staff members and other members of educational community present for public lesson

May 5, 2009	Wrap up, data analysis	Team met for full day with researchers to analyse their student and teacher data

4.3.3 Findings

The findings are organized in two broad categories: student learning and teacher learning.

a) Student Learning

Student mathematics communication

Students at this case study site were explicitly introduced to the Math Discourse Guidelines (Bruce, 2007; see Appendix D) to facilitate math-talk in the classroom community. In exploratory and public lessons, students were observed communicating effectively using math vocabulary as well as following the discourse guidelines (Debriefing Nov. 26, 2008 and May 1, 2009). Leading up to the November public lesson, the Grade 1 teacher did an exploratory lesson with her students, which involved a modified version of the task the team had designed for the Grade 7/8 public lesson. In the Grade 1 class, the teacher had students debating, in pairs, which was greater: one half or two quarters. To support student communication, the teacher had given students popsicle sticks with the communication stems "I agree" and "I disagree" printed on them. Students could choose which stick they wanted to put down on the table depending on whether or not they agreed or disagreed. Then they were to present their reasoning to their partner. Pedagogically, the popsicle sticks were intended to get students really thinking about what it meant to disagree or agree, to make a deliberate choice based on reasoning. In classroom video taken by the teacher, the students appeared to be using the stems highly effectively. In one particular pair, captured on camera (15+ minutes), the popsicle stick really did support a student in disagreeing with the dominant argument of her partner, in spite of the fact that she clearly felt a pressure to agree and go along with her partner. In this case, the framework for language provided by the math discourse guidelines appeared to be used effectively and provided structure and support to student discussion.

In the public lesson that followed shortly after, teachers again observed student-student communication using the guidelines and accurate math vocabulary. They heard students agreeing and disagreeing with one another, although in many cases, they "didn't hear the typical [exact] stems" (Debriefing Transcript, Nov. 26, 2008).

In January, one teacher noted that her students were using the discourse guidelines in other subjects, without prompting (Field note, Jan. 15, 2009). By the end of the 2nd term, this same teacher reported her students were using the stems "very comfortably" (Field note, Mar. 24, 2009). She was encouraging student-student communication by handing over control to students: "I was stepping out and they were stepping up" (Field note, Mar. 24, 2009). Teacher had the guidelines posted in their classrooms as a further reminder of how a math discussion might be framed to build understanding.

It is interesting to note that students seemed to be able to access and internalize the language for agreeing and disagreeing first. It was less common for students to "build on" or "go beyond," indicating that these are possibly higher level ideas that require further scaffolding, modeling and support.

Student communication while using the IWB

One of the goals for the team for this year was to explore ways to engage students with the interactive whiteboard to investigate problems. In establishing their goals, the team identified the IWB as a type of manipulative (Field Note, Oct. 3, 2008) and sometimes used it as one of several centres where different manipulatives were used to investigate one problem, as was the case in the Grade 1 public lesson in May. In this 3-part lesson, the teacher began by leading a discussion with the interactive whiteboard as a stimulant for thinking (recording student ideas on the IWB). In the development stage of the lesson, two students were assigned to the IWB to solve a problem involving transporting a combination of children and adults in vans and cars. During consolidation, the student work was immediately available for others to see and discuss.

In the lesson study debriefing, several teachers shared notes about one of the students, known to have limited verbal communication skills. One teacher was please to see him up at the IWB, "so animated and participating well" (Debriefing transcript, May 1, 2009). The SERT, who was also present as an observer at the public lesson, also took special interest in this student's activities and interactions at the IWB, which she described as "incredible". She indicated that these observations were helpful to her understanding of the student.

Later in the same debriefing, another participant noted that the students at the IWB were able to work through more solutions than did the other students. One teacher noted that this was consistent with her observations of her own students since her IWB was installed, who she noticed "got to work quicker, worked more efficiently and collaboratively, [and] got more solutions" when given the opportunity to work on the IWB (Debriefing transcript, May 1, 2009).

b) Teacher Learning

In all cycles of this lesson study project, great care went into the development of the observation guides that were used during public lessons. These guides were targeted on specific aspects of the lesson and student responses/interactions that the teachers were most curious about. At the debriefing, all participants shared their observations in a somewhat formalized manner, following protocols developed in Japanese Lesson Study.

Teacher learning was expressed, through deeply involved discussions about what teachers heard and saw students say and do, particularly during the exploratory and public lessons. After analysis of all data, three key areas of teacher learning were clearly identifiable: (i) management of materials and scaffolding to enable students without over-leading the students; (ii) approach to teaching mathematics from a problem or inquiry base; and, (iii) understanding of the purposes and value of student mathematics communication.

Managing student scaffolding (manipulatives, tasks, questioning)

Teachers grappled with what they and the other teachers saw and heard. Some of this learning reinforced general learning about effective teaching practice. For example, in both the November and May public lessons, the teachers observed some barriers to student learning that involved how students organized the manipulatives for investigation of the problem; inefficient selection or use of the manipulatives led to questionable outcomes for these students. Also, in both lessons, teachers observed that the strategies for recording solutions as students performed the task impacted on potential student learning. They offered one another suggestions for handling the manipulatives to minimize these problems. For example, one teacher suggested having students talk through the problem first – before receiving the manipulatives and diving into the investigation – to give them a chance to develop a strategy before being potentially overwhelmed or distracted by the manipulatives (Debriefing transcript, May 1, 2009). Their observations reminded teachers of the importance of careful selection and management of materials, and indicated that they were wrestling with how much scaffolding to provide in the recording of solutions, issues that effect student learning across the curriculum but are particularly important to the building of conceptual understanding in mathematics.

Another example of learning about effective teaching practices involved wrestling with the question of how much to "give away" and how much to deliberately allow students to struggle with tasks and concepts. In the debriefing to the May public lesson, one team member noted how interesting it was to see how much time the teacher took ensuring that students understood the question.

> And I always have that struggle, if I set up that question a lot, they're more likely to get an accurate answer, but is that what I want today? Or do I want to let them struggle? But then it also gives them the opportunity to go way off in the wrong place. So that's something that I deal with every time I set up a question.

Another team member noted to the teacher of the public lesson:

> The way that you phrased your questioning was really open. Your questioning was really good, it was so open, it really required them to come up with the thinking, and I found that really admirable. And also, you had really good wait time….you sat and you said, hmmm, only two people know that? And you waited. And eventually, more hands went up.

Later, this same teacher wondered about her own questioning of students as a result of observing the teacher in the public lesson, acknowledging that she saw this as an area for growth. Her discussion about the teacher questioning tied back to the discussion around how much to give away and how much to allow students to struggle:

> Something that kind of was a light bulb for me today was the open-ended questioning. And I always find that really hard, to find the question that's going to not give away too much and get out what I want.

This teacher set a goal to work on her open-ended questions and suggested that the team spend some time developing a template for considering the quality of questions. This kind of dialogue indicates that the observation of the public lesson led teachers to not only engage with what they saw and heard, but to reflect back and make connections to their own practice. This reflection allowed teachers not only to pinpoint areas for growth, but also to brainstorm together on strategies for improvement.

Problem-based teaching

The teachers reported a change in their approach to mathematics teaching as a result of their foci in the project over the two years (problem solving using open-ended tasks, investigation using manipulatives including the IWB, and math communication). During the debriefing sessions and in interviews, the teachers reported tension in finding a balance between "covering" the curriculum and pursuing deeper learning and conceptual understanding for their students through a problem-solving approach. The teachers found a problem-based approach to have positive outcomes, in spite of this perceived tension.

First, they recognized and valued the ways in which a problem-based learning program encourages rich discussion and deep learning in the classroom. As one teacher put it:

> I feel one billion times better about the math teacher I am … I feel like I'm so much more effective… we just had a 45-minute discussion today about how many faces a cylinder has and I bet they learned more in 45 minutes than they did opening a textbook and identifying three-dimensional solids and putting that in their math workbook. (Debriefing transcript, May 1, 2009)

Second, teachers found they had raised expectations of their students and that, in turn, students were rising to meet these expectations, as exemplified in the following statement: "I feel like what I'm doing is so much better and more thorough and the understanding that [what] I'm expecting far exceeds anything that I used to expect. And I'm getting more" (Debriefing Transcript, May 1, 2009). Finally, teachers realized that they were indeed going broadly across curricular expectations, as well as deeply within a concept, because with rich tasks, "you are doing so much with one lesson" (Debriefing Transcript, May 1, 2009).

Not only did this team of teachers learn about inquiry approaches to mathematics, they implemented this approach consistently in their classrooms, as observed in over 20 videoed episodes, with the support of one another, researcher facilitators, and with the support of the lesson study structure as their PD model.

Teacher learning about Mathematics communication

At the beginning of the year, the Grade 1 teacher-participant struggled to visualize how math communication would unfold in her classroom. She wondered what math communication could sound like in Grade 1, when students have fewer connections to make (Field note, Oct. 23, 2008). A month later, this same teacher jumped into giving an exploratory lesson, which was a modified version of the task that was going to be used in the Grade 7/8 public lesson. In the exploratory lesson, this primary teacher video taped her students talking in pairs and in whole group and shared the video with researchers.

A month later, in the Grade 7/8 public lesson, the team had refined the task for a public lesson, with further scaffolding that was intended to get students using the communication stems (agree, disagree, build on, go beyond). The lesson was a modification of a TIPS lesson on fractions. Students were given a problem to solve: Three people want to share a small cake. There are four ways they might choose to split the cake. <u>Which of the following statements are possible?</u> Explain your reasoning.

a) Emily ate $^3/_8$ of the cake, Esther ate $^1/_4$, and Daniel ate $^1/_2$.
b) Emily ate $^1/_5$ of the cake, Esther at $^3/_{10}$, and Daniel ate $^1/_2$.
c) Emily ate $^1/_3$ of the cake, Esther ate $^1/_2$, and Daniel ate $^1/_6$.
d) Emily ate $^1/_6$ of the cake, Esther ate $^1/_4$, and Daniel ate $^1/_3$.

Students were encouraged to use math-talk sentence stems such as "I agree because" and "I disagree because" to help them organize their thinking, as well as a variety of manipulatives. In the debriefing session after the public lesson, one teacher remarked:

> I didn't hear as I was circulating, the communication stems being used. But every group was talking so, is the stem that important? That is the question I'm asking myself, so we can talk about that. And then in terms of the consolidation, pulling those stems out of them was really hard and kind of tweaking what they said to make it fit the stem was a challenge to do on the spot. I'm not finding their using that "because" part very deeply yet … considering how some of them didn't use it at all to start with, maybe the fact that they're using it superficially is still a sign of growth, but that will be something will want to look out for in phase 2. (Debriefing transcript, Nov. 26, 2008)

This comment illustrates how the teacher was grappling with the implications of the forms that math communication took among her students. The team had set a goal of scaffolding to get students using the stems and built the lesson to facilitate that type of communication. Their goals for the lesson indicated that they expected students to use the stems. When she observed limited use of the stems, instead of seeing this as a failure of the students or a failure of the lesson, she recognized it as a sign of growth that they were using math-talk at all, and saw this as a foundation that the teachers could be built upon in their second cycle of lesson study. The teachers recognized that the forms of communication observed were legitimate and meaningful for the students.

The observations of student communication during the Grade 7/8 public lesson further led to critical analysis of the task. The group agreed that they did not observe as much communication as they had anticipated. All of the teachers on the team questioned whether the task itself had limited the potential for student communication. As one teacher asked, "one thing I was wondering was … was the task rich enough to promote the talk we were looking for? (Debrief, Nov. 26, 2008) The group seemed to agree that perhaps the task was not challenging enough and was too easily solved using the manipulatives. This led to a rich discussion about the types of tasks that could promote student discussion.

The observation that students communicated less than expected in this lesson also led teachers to discuss strategic groupings of students for group work. The team had decided to put the students in groups of three, but in the debriefing agreed that groupings of three were not ideal for their purposes:

> I think a group of three versus a group of two… a pair would have had to talk more. Personally, I think, looking back when you are in the threes, it's really easy for one person to sit back. (Debriefing transcript, Nov. 26, 2008)

The fact that teachers went from being unsure of what math communication could look like and sound like in their classrooms, to describing the nature of the math communication taking place among students in exploratory and public lessons, to engaging in constructive conversations about particular strategies for encouraging more student communication indicates the arc of their learning through the course of the project.

c) Teacher Collaboration

The collaboration of the teachers through lesson study was the vehicle that drove their learning. The collaboration – and any attempts to improve and expand on the foundations of collaboration established in the first year of the project – was purposeful and deliberate on the part of the team. The teachers who were involved in the first year of the project found the collaboration to be so powerful and transformative, that they set about expanding the team in the second year, asking the Grade 1 teacher to join the team so that they could benefit from the added perspective from the primary division and henceforth be a truly cross-divisional team. The cross-divisional nature of the team was a first for the school; in the past, collaboration had taken the form of mandated division-based PLCs.

Including teachers beyond the team

The team had a secondary goal of further expanding the collaboration by involving other staff members. In doing so, they wanted to expand their colleagues' understanding of the purpose and process of lesson study by inviting teachers beyond the team to take part in exploratory and public lessons. They also sincerely wanted the input of their other colleagues in developing the exploratory lessons and hoped that their participation might lead to an increased culture of collaboration at the school.

The first public lesson of Year Two, in November, 2008, was attended by another junior-division teacher as well as two math/literacy coaches who worked in the school. The second public lesson in May, 2009 included many more staff members – five teachers, including the Learning and Life Skills teacher and the SERT, took part in the observations and debriefing, giving them their first experience of the formal activities of lesson study.

Use of "exploratory lessons"

Perhaps even more importantly, the team had set a goal for this year of enacting exploratory lessons that would involve additional staff members (Field notes, Oct. 3, 2008). Exploratory lessons allow lesson study participants to see in advance of the public lesson how different elements of their lesson may function with different students with a view to understanding student learning, and to making refinements to the lesson. In the case of Hillside, the team saw these exploratory lessons as an opportunity to further engage other staff in the activities of lesson study. In their planning for the May public lesson, they wanted to use an open task that would have entry points for students at different levels, and they were curious as to how the question would work (with minor modifications) in Grades 1 through 8. They were successful in engaging colleagues to try the lesson with their students, and as a result, the same problem was enacted in every grade level throughout the school. The other teachers took notes about what happened in their classroom (observation notes), with an emphasis on what surprised them, and circulated these to the lesson study teachers. The notes were made available to all those who attended the public lesson, for information. The lesson study team used the information to refine the lesson based on the verbal and written input from their colleagues.

Teachers on the team were very excited about the outcomes of the exploratory lessons. According to one of the teachers on the team, the exploratory lessons "opened doors for math dialogue to perhaps occur on a more regular basis" in the school. The staff members who took part in the exploratory lessons shared this excitement. One staff member shared this experience at the debriefing of the May public lesson, saying that it was interesting to see learn how the students had responded across the grade levels, and that just the fact that they had done something like this school-wide was "amazing" (Debriefing Transcript, May 1, 2009).

Alignment of PLC goals with lesson study activity

The collaboration of the teachers in this case did indeed appear to have a school-wide impact. One significant development in this area occurred when the teachers were able to align their Professional Learning Community (PLC) goals in numeracy with their investigation of math communication in lesson study. Their work has also appeared to expand the use of and excitement about IWBs in the school (Interview, March 24, 2009). In planning for the 2009-2010 year, staff decided to engage in a simplified lesson study process as the structure for their PLC activity.

Overall participant engagement in collaborative professional learning

Overall, the enthusiasm of the lesson study teachers for the collaborative activity of the project cannot be understated. At the outset of the second year of the project, one teacher reflected on her experience:

> Last year, participating in the Lesson Study project was the first time in my whole life that I actually felt really good about a math lesson I had taught. That public lesson was the result of 3 heads (and more) coming together to create an amazing lesson that met an incredible goal. We walked away thinking about how well things went, but more importantly, how we could improve or progress the

next time. (Journal entry, Oct. 6, 2008)

When asked what aspects of the project were most helpful to her learning, another intermediate teacher reflected similarly:

> Working closely with other teachers, especially those from other grades, was very helpful for me to advance my understanding of teaching math. I have not had the chance to see primary/junior math very often, and working closely with teachers in these divisions is giving me a much better sense of the bigger picture. Also, the chance to work with a grade-alike partner advanced my learning because I was able to bounce ideas off another person who is dealing with many of the same issues/concerns as I am. The opportunity to sit down and discuss the finer points of a task or a lesson has taught me a lot about just how much thinking or considering can go into making our lessons better. Discussing student outcomes has led to a deeper appreciation for seeing things from a student's perspective (i.e. how they perceived the task in the first place). (Questionnaire, May, 2009)

This teacher's response focused squarely on the different aspects of professional collaboration, and underscores the importance of collaboration to the teachers' learning.

It is important to note that at their January meeting, which was the first lesson study activity following the November public lesson, teachers reported feeling less enthusiastic about their math teaching, and reported feeling disconnected from their goals in the project. This indicates the need for opportunities to reconnect with one another and the goals of the project on a regular and on-going basis, bearing in mind that school breaks and other demands may conflict with this need.

Case Study: Pine View High School

A second lesson study site was also fully analyzed and written up as a short report for support of the cross-case analysis.

4.3.4 Background

a) School Context

Pine View High School is located in a growing town of 16,000 residents, in central-Eastern Ontario along the shores of Lake Ontario. Pine View's enrolment of 708 students, combined with its senior public school population of 300, brings the student population to approximately 1000 students. The town in which Pine View is located is described as a thriving community with strong economic development plans in place. Less than 10% of Pine View's students come from lower-income households, as opposed to the provinces 16.5% average. 18% of the school's population comes from households that have some university education, with 1% of its students identified as gifted (.3% below the provincial average) (School Information Finder, 2009).

Both academic and applied streams tested above the provincial standard according to EQAO scores for Grade 9 math (75% of academic students at or above standard and 34% of applied students at or above standard) by 3% and 4% respectively. Over three years, Pine View's provincial scores have risen 15 percentage points, with applied scores rising 10 percentage points. Literacy scores show to be just under the provincial standard, but are also rising.

Upon entering Pine View, visitors are greeted with the activity of students cleaning or adding truly unique art to the walls. Walking the halls, it is evident that the Pine View staff has high standards for their students.

b) Background of Teachers

Two of the secondary teachers involved with Lesson Study in 2007-2008 continued on the team for 2008-2009. These teachers had participated in two full cycles of lesson study in the first year and were confident with the process to guide the 3 new members along. Thus, the team grew to five members (three secondary teachers and two intermediate teachers). One of the teachers on this team had previously won an international teaching prize for her use of the interactive whiteboard in mathematics and this added further expertise to the team in terms of the incorporation of the IWB into math lessons.

4.3.5 Team Implementation

a) Areas of teacher team emphasis (goals)

The main team goals were:
1. To create a carefully crafted lesson on the concept of 'volume' that was to be taught to Grade 7-9 classes, in order to assess how and why students were missing this key math concept;
2. To attempt to improve the curricular transition from intermediate grades to high school;
3. To develop strategies for facilitating high quality mathematics communication.

The team had a hunch that students could understand how to find volume, but they did not understand the concept of volume (and what it meant) – a key idea, deeply connected to math communication. Reflecting on the previous year's experience, the Pine View team wanted to develop and revise a particular lesson until it was 'perfect' through one cycle of lesson study; with four exploratory lessons and one public lesson, each teacher would have the opportunity to teach the lesson to their own class, with the support of the lesson study team. This proved to be a beneficial strategy for both teachers and students.

b) Teacher team activity

The teacher team planned to complete one lesson study cycle with 4 exploratory lessons and 1 public lesson. The lessons were to start in a Grade 7/8 setting, and culminate in a Grade 9 classroom. The group met weekly for an hour after school to plan their lesson until the first exploratory date of April 6th, 2009. Below is a table that outlines the major activity of the Pine View teacher team during their lesson study activity.

Table 4
Pine View Lesson Study Schedule

Date	**Event**	**Description of Activity**
February 10, 2009	Planning meeting (1hr)	Goal setting (researcher present)
February 19, 2009	Planning meeting (1hr)	Planning exploratory lesson (researcher present)
February 26, 2009	Planning meeting (1hr)	Planning exploratory lesson (researcher present)
March 26, 2009	Planning meeting (1hr)	Planning exploratory lesson
March 30, 2009	Planning meeting (1hr)	Group to run through lesson
April 6, 2009	Exploratory Lesson (1/2 day)	Grade 7/8 math class (observers and researchers present)
April 15, 2009	Exploratory Lesson (1/2 day)	Grade 7 math class
April 30, 2009	Exploratory Lesson (full day)	Grade 9 academic math class (observers and researchers present)
April 30, 2009	Exploratory Lesson (full day)	Grade 9 academic math class (observers and researchers present)
May 5, 2009	Public Lesson (full day)	Grade 9 applied math class (observers and researchers present)
June 19, 2009	IWB Workshop	Focus Group meeting to reflect on teacher learning

4.3.6 Findings

a) Student Learning

The Pine View team was a model group for lesson study in their willingness and drive to generate more math talk throughout their lessons. The group embarked on creating a lesson that would get students to be active with one another, in hopes that students would begin to understand what volume is and its relationship to calculation procedures. Teachers felt that from Grades 7-9, students were missing this understanding, and it was beginning to have a negative effect on students' math talk and overall understanding of math.

Concerns about student lack of understanding

The Pine View team chose to focus on volume and it's meaning because they found it to be a critical part of student learning when dealing with any type of perimeter and area based problems. It was noted that students were confusing area and volume. The teachers felt that they needed to start with the vocabulary, getting students to define volume in pre and post tests to see what they actually knew. In February's second planning meeting, teachers arrived with their pre-tests, immediately stating that students were upset at the test and had struggled with many of the questions. Few students could define volume, and those who did received one mark for stating that 'volume is the space inside an object'; students were to receive two marks for identifying that 'volume is the space inside a 3D object' – only a handful of students out of the five classes used this definition.

The lesson generated from these concerns included six stations for groups of students to rotate through; each group would have the chance to visit three of the six stations. Each station consisted of a different problem, requiring students to find volume of: (1) a heart shaped box, (2) trinomial manipulatives, (3) quadrilateral manipulatives, (4) an oval cylinder, with (5) and (6) being stations at interactive whiteboards to manipulate virtual cubes and find the volume of the figures.

Increased understanding through exploratory lessons

During the consolidation phase of the initial exploratory lessons, it became clear to the observers and researchers that students understood how to calculate volume procedurally, but still could not communicate what volume was and how they knew that their solution was in fact the space occupied within a 3D object. Through debrief after the first exploratory lesson, it was agreed that students needed an activation or 'minds on' activity that would relate volume to real life situations.

In the third exploratory lesson with a Grade 9 academic class, students were introduced to a fish tank (on the interactive whiteboard) that was filled half-way with water. When the teacher asked what would happen to the water when she dragged the fish into the tank, students immediately responded with, "the water will go up". The teacher then asked students how they could find the volume of the fish. One student in the April exploratory lesson said, "if we took the fish out and measured it, it might die". Students looked puzzled as to how they could find the volume until one student finally noted that they needed to find the initial volume of the tank, and the volume of the tank after the fish was added. The student stopped here and was unable to figure out the rest of the procedure, until another classmate said that they needed to subtract the initial volume of the tank from the volume of the tank with the fish in it. Once students were able to put these pieces together, they visually could see what volume was before, during, and after the addition of a 3D object. Therefore, their pre-existing understanding of how to use the procedure was now connected to a conceptual understanding of volume.

Finding volume within a variety of 3D objects, however, did not always present itse lf as being simple. In April's Grade 9 academic exploratory lesson, a group of boys created a star shape from quadrilaterals that consisted of six points and three layers of the manipulative. Instead of measuring the base by the height of their shape, the boys found the volume of one quadrilateral, and multiplied it by the number of pieces they used. This was both interesting and confusing to students during consolidation, but informative to the conversation between them. In another case observed in May's public lesson, a boy and girl were at the station with the oval cylinder (the station included grid paper and rulers). The pair were puzzled as to how to find the volume of the cylinder and deliberated for quite some time. Eventually they agreed that they would take the grid paper (grid facing up) and fold it over top of the oval cylinder, and then count the cubes that were flat along the top to find its base. One student demonstrated his understanding that this method would only approximate the volume of the cylinder, when he stated: "when you're using grid paper, it's always going to be an approximate anyway".

Student communication in the mathematics classrooms

The first of four exploratory lessons saw groups of four students in a Grade 7/8 setting. Math talk was strong and consistent when students were observed, but students seemed to only respond to problems when a teacher was present at their table. When the teacher left, it was as if students were afraid to move forward and the communication was lost. The consolidation component of the lesson was fruitful, and generated teacher discussion in reflection. This led the teachers to revise the exploratory lesson, for two reasons:

1. Insufficient time was given for consolidation;
2. Student responses were all procedural with no demonstration of conceptual understanding of volume.

The second exploratory lesson with a Grade 7 class was very similar. The third and forth exploratory lessons were taught to two Grade 9 academic classes with students in groups of four. Math communication with appropriate vocabulary was consistent, however students were very quiet and at some points hard to hear. Each group had a different dynamic of problem solving, and it was observed that at least one student from each group was disinterested and un-focused, but not disruptive to the group. The teachers were still not satisfied with the level of student communication.

During the fourth exploratory lesson, a group of students created a star shape using quadrilaterals, and generated their own procedure for finding the volume; this created much discussion in the consolidation of the lesson, however, once again, not enough time was left in the period and the discussion had to end.

It was in the final public lesson that the months of collaboration and practice finally came into fruition where math communication was driven by the students. Twelve students were put into pairs, each working on a different problem. Students were consistently engaged with their tasks. From Pine View's May public lesson, each pair of students were observed. The following are three representative examples of the observations made:

> *"Pair One (a boy and girl) looked through all materials, talked about what they had done in class using prior learning to move to the next step. Math language was on target with basic geometry terms. Members of pairs asked one another how to start, explained solutions in words, and used more hand gestures than verbal communication. When lacking understanding, the students asked one another, shuffled papers, shrugged, or asked the teacher for help.*
>
> *Pair Three (two boys) demonstrated parallel play at the interactive whiteboard for both of the activities. When an adult was present, they remained equally interested in what they were doing. Checking with one another, "What did you get?" "Where are you now?", asking questions for help, processed independently, used strong math language that was in context, used gestures like raising eyebrows, nodding, and looking to confirm each other's work along the way. One of the boys challenged himself by not using the calculator provided. Boys looked for confirmation and first steps for each of their activities when teacher was present.*
>
> *Pair Six (boy and girl) read questions to one another, both relating things from previous lessons and bringing this forward, "Does this make sense", asked about having a 'complete answer' regularly. With oval bottom asked "are top and bottom same size?", "What is a prism? What is volume? What is the area of the base? How do the layers increase the height? Oval – what does Pi r squared mean? How do you find the radius for an oval?" They talked the entire time. Deliberated over strategies.*
> *Some confusion over area and volume - had to keep coming back to this. Issues with mm to cm and conversions. Discussed height of triangle versus height of triangular prism and matching/congruent bases." (Field notes, May, 2009)*

It is clear that given the opportunity, students deferred to the teacher to check for understanding and then moved forward. It was later in the debriefing that the public lesson teacher explained that strong math students had been paired with weaker ones. It was observed that the stronger students led these pairs, and openly helped the struggling student, showing patience and support at each station. By the end of the public lesson, through the consolidation, students were observed to have a very clear understanding of volume of prisms. On more than one occasion, as students left the classroom to get their next class, teachers overheard students making comments such as: "I didn't know math could be so much fun".

Student communication using the IWB

The use of interactive whiteboards in the Pine View exploratory and public lessons were unique and uncommon to the average classroom. The 6 stations included 2 interactive whiteboards at opposing ends of the room. Direction was still needed at the interactive whiteboards, however, once students were prompted on how to use the board (by the refined public lesson) students were able to take complete control. In a focus group discussion after the public lesson, one teacher stated "and a lot of our kids didn't grow up with SMARTboards, so they're not coming with a whole lot of knowledge, so you really need someone to help set up the SMARTboards" (Focus group interview, June).

Throughout all five of Pine View's lessons, it was observed that students were engaged and comfortable using the interactive whiteboards. In April's first two exploratory lessons in Grade 7 and 8 settings, students were seen as "engaged, boisterous, loud, frustrated, and generally interested in what was happening" at the interactive whiteboard. The remaining two exploratory lessons that took place in Grade 9 academic settings in April were quite similar. Students who were observed as being disinterested in their groups work at the tables (with an object or manipulative), seemed more alert and inquisitive when it came time to work at the interactive whiteboard. The public lesson in May showed students equally engaged, sharing and comparing work; students were observed challenging themselves at each station including the interactive whiteboard stations.

The interactive whiteboard seemed to be engaging to all students. It further generated math talk while partners worked through problems at the board; communication that focused on mathematics and was beneficial to increasing student understanding.

b) Teacher Learning

Some key teacher learnings that came from this year's lesson study noted by the teachers were the importance of: (1) exploratory lessons (being able to practice and revise the lesson they created before finalizing it); (2) the time allocated to consolidation at the end of each lesson; and (3) students working in pairs (and its effectiveness towards generating math communication).

Learning from exploratory lessons

In the first and second exploratory lessons (Grades 7 & 8), teachers observed that students were not using the proper math vocabulary when communicating in math; they often rebutted their peers findings when presenting and put forth basic questions that had little weight to the solution at hand. With a lot of teacher direction, students struggled with the problems individually and as a group. Their understanding of volume was found only in the procedure of volume, and not in the concept of volume; little time was left for consolidation when it came time to having students convey their conceptual understanding.

In the third and fourth exploratory lessons, teachers started to see some real growth in the lesson. Student mathematics vocabulary was very strong, but students were quiet when communicating to their partners. Although it was quiet, the students remained completely on task and required little if any teacher direction at the stations. The students were older (Grade 9 academic classes) and the independent work of the students could be attributed to this. Time for consolidation was still found to be too short.

The team had recognized that in the exploratory lessons, good questions from the students were arising, but little time to unpack and discuss them was available. This was frustrating to the teachers. Drawing on these learnings, the Pine View team revised their final lesson by cutting down the rotation of the students to each station from 3 to 2, leaving more room for consolidation and by selecting the most effective tasks and manipulatives for the final version of the lesson.

Teacher learning about the value of consolidation

Teachers were very interested to see how valuable time for consolidation was for math communication and student understanding to occur at higher levels. It had taken four exploratory lessons at Pine View for the teachers to decide to cut down the student rotations through the stations in order to leave an extra 15 minutes for consolidation (on top of the ten minutes planned for consolidation in previous lessons). Observers were able to see the wait time required for students to listen and understand what their peers were saying as important. And teachers found they had more time to explore alternate answers/solutions rather than listening for the right answer, and moving on. During the debrief, teachers explained the value of consolidation as follows:

> Teacher 1: I found that the weaker student was starting to get the hang of it, and timing was perfect, and enough time for consolidation was beautiful, kids were 'hands up' and stuff. The questioning of why they were getting what they were getting, we had time for that to happen.
> Teacher 2: It wasn't rushed.
> Teacher 3: Which it was, with I think the two Grade 7 ones because we didn't have the time to consolidate really.
> Teacher 4: I think we realized the importance of that, as we went through the exploration. When we first put it together, our focus was…what are we going to do at these centers, and we put so much time into that, when really, the real nuts and bolts of it that we found out was, the discussion piece at the end.
> (Debrief, April)

Consolidation time proved to be important for the teachers to observe and evaluate what students had been learning through math communication. Students were able to demonstrate and solidify their understanding during the consolidation when time was provided to do so.

Teacher learning about student group work

One of the key learning's that came from Pine View's exploratory and public lessons was that students working in pairs maximized communication; math communication was more focused and constant in pairs.

> We fine tuned our grouping strategies too – in say a group of three, it was always easier for one student to pull away from the activity. In groups of four we found that the two weak students would go together, and the two strong

> students would go together…so now we're just going to have pairs. (Exploratory Debrief)

Students were also observed to be more focused and motivated to complete their problem by the time they moved onto the next station knowing that at the end of class, they would be presenting their findings. Teachers learned that creating multiple problems that students would circulate through, offered challenges that scaffolded students to find volume in a variety of ways while interacting with their partners.

c) Teacher Collaboration

Bridging the gap between elementary and secondary schools
Comprised of teachers in their first and second years of lesson study, the Pine View lesson study group were truly exemplary in their willingness to collaborate and learn how to create a math environment filled with talk and understanding. They planned to have one key lesson implemented and refined through Grades 7-9 respectively. The Pine View team met weekly after school for an hour to plan as a group and reserved all their allocated release time to observe during exploratory lessons. Different teachers took leadership roles through the planning stages while the other participants were attentive and engaged in the session's activities. Teachers were excited to learn about how they could create a lesson collectively that would generate math talk.

Teacher planning
In February, teachers planned and administered a pretest on volume, and used the results to brainstorm what types of questions would work well in their lesson to support students in the areas they struggled with on the pretest. From there, the team met each week to discuss the overall structure of the lesson and to work out details specific to the station activities. This was followed by sessions where teachers developed the Notebook files and tested their fluency with the rest of the lesson.

Teacher reflections on group dynamics
Teachers found it valuable to have the opportunity to work with and learn from colleagues from different grade levels. In a focus group meeting in June, one team member spoke with regards to the importance of the collaborative planning of the exploratory lessons:

> Then we went through, then tweaked and changed and changed and changed and added and even down to the very last lesson we made changes. And I liked that we were able to do that, and I saw growth that way. I liked working with the 7/8 teachers, just to see that curriculum – we don't do that enough. We talk about EQAO scores…but it never really goes any further than that. (Focus group interview, June)

The group later commented that "it seemed to take us forever to get that lesson." The group felt that working with such a large number of colleagues made it difficult to agree on an idea because it had to go through everyone. However, they recognized that the time taken to get the final lesson was well worth the outcome when they watched the public lesson. Motivated by the outcome of this year's lesson study, the Pine View team was excited to share the lesson and their experience with the rest of the staff, in hopes of sharing with them the value of co-planning and co-teaching.

4.4 Quantitative Results for Lesson Study

The quantitative findings confirmed the case study data showing that participation in lesson study had positive effects on teachers. We conducted a series of repeated measures analysis using pre- and posttest scores for each of the teacher outcomes. Table 5 displays the pre and posttest means and standard deviations, the results of the repeated measures analysis of variance, and the effect size (Cohen's *d*). The results were consistent: teachers had higher scores on all teacher measures (math teaching practices, collaboration, and the three measures of teacher efficacy) at the end of the in-service than they had at the beginning. However, none of these differences were large enough to reach statistical significance in such a small sample. The effect sizes were small, except for the positive impact on teachers' self-reported teaching practices, which was of medium size.

Table 5
Effect of Treatment on Teacher Beliefs and Teaching Practices for Lesson Study Teachers (N=11)

Teacher Outcome	Pre		Post		GLM Results	ES
	Mean	SD	Mean	SD		
Math teaching practices	4.57	.30	4.80	.35	$F(1,10)=2.62$, $p=.137$	.71
Collaboration	4.68	.93	4.76	.92	$F(1,10)=.322$, $p=.583$	.00
TE: student engagement	3.73	.49	3.82	.48	$F(1,10)=.278$, $p=.603$	.19
TE: instructional strategies	4.20	.71	4.30	.53	$F(1,10)=.477$, $p=.519$	.16
TE: classroom management	4.36	.56	4.45	.35	$F(1,10)=.510$, $p=.492$	.19

TE=Teacher Efficacy

Since the lesson study focused on a particular lesson, Pine View teachers constructed a test that measured the knowledge and skill addressed by the lesson. This content test consisted of four items: 'Define' asked students to define volume, the core concept of the lesson; 'Cube' was a chart that asked students to draw and write out the dimensions of a figure when given its volume; and the 'Volume' or 'Height' items asked students to find the missing height or volume from the dimensions given in the prompts. Table 6 shows the results of the pre-post comparisons. We found that student achievement improved from pre to post on all scales; the improvements were statistically significant, albeit small.

In summary, when we measured content specific to the focus of the lesson study we found evidence of student learning. The results of the district tests suggest that the achievement gains did not include improvements in mathematical processes that extend beyond the content of the target lessons.

Table 6
Pine View Student Achievement Means, Standard Deviations, Effect Sizes and GLM Results by Content Task (N=91)

Achievement Value	Pre		Post		GLM	ES
	Mean	SD	Mean	SD		
Define	0.80	0.73	1.37	0.69	F(1,90)=37.00, p<.001	.29
Cube	4.68	4.42	6.41	4.54	F(1,90)=7.43, p=.008	.08
Volume	1.50	1.49	2.55	1.66	F(1,90)=20.81, p<.001	.18
Height	1.04	1.42	1.95	1.54	F(1,90)=20.85, p<.001	.19

5. KEY FINDINGS

5.1 Demonstration Classrooms Summary Findings

In Oriole Park, the qualitative study showed that powerful teacher learning was enabled through the context-embedded nature of the observation experience; what teachers saw was grounded in the reality of the classroom and thereby made accessible and relatable. Teachers were able to immediately implement features of the classroom or the lesson in their own classes upon return to their schools.

The strategies teachers learned through observation included:

a) organizing the classroom to facilitate consolidation;
b) finding and adapting resources for problem-based learning, including ways to adapt the textbook for a problem-solving classroom;
c) designing asset-oriented differentiated assessment pieces based on the big ideas;
d) grouping students strategically based on needs and immediate learning goals rather than ability.

These affirmed their goals of establishing high quality math communication in their classrooms and continuing to hold high expectations for students and for themselves in continuing to hone their implementation of the three-part lesson, especially consolidation. The experience also led to renewed collaboration among the teachers, which spilled over to other staff members in the school. For one teacher, this experience powerfully reconnected him to his goals for teaching in math and renewed his enthusiasm for math and math teaching.

The quantitative data confirmed these findings; teachers in the demonstration classroom treatment reported that they were more collaborative after participating in the in-service than they were before and their self-reported use of Standards-based mathematics teaching increased.

Overall, the quantitative data confirm the case study findings that the classroom demonstration in-service contributed positively to teacher's knowledge, beliefs, and self-reported practices, with particularly strong effects on teacher collaboration.

5.2 Lesson Study Summary Findings

As qualitative data were collected over a multitude of classroom observations over the course of the school year, and include data collected during public lessons (which are purposeful in their observation of student responses to features of the lesson), qualitative researchers were able to make some direct observations about student math communication and student use of the interactive whiteboard (both teacher goals in the case of lesson study). 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 math communication.

Six key areas of teacher learning were identified:

a) management of materials and scaffolding to enable students without over-leading the students;
b) teaching mathematics from a problem or inquiry base meets curriculum expectations deeply (shifting from math teaching as “coverage” to multi-stranded tasks that build conceptual and procedural understandings);
c) understanding of the purposes and value of student mathematics communication;
d) refined teaching strategies and lesson plans through exploratory lessons;
e) the value of consolidation in the three-part lesson;
f) the importance of grouping students strategically to maximize peer communication.

As with the demonstration classroom case, teachers in lesson study found the collaborative nature of their work to be exciting and satisfying, and found ways to extend themselves to collaborate with other staff members beyond their team. Overall, the enthusiasm of the lesson study teachers for the collaborative activity of the project cannot be understated.

The quantitative data confirmed these findings; teachers had higher scores on all teacher measures (math teaching practices, collaboration, and the three measures of teacher efficacy) at the end of the in-service than they had at the beginning (though it should be noted that none of these differences were large enough to reach statistical significance in such a small sample).

Interestingly, content specific improvements were found where the pre and post-tests were directly focused on the content areas that teachers had targeted for improvement. This is important because it may be a foreshadowing of improvement across other areas of the mathematics curriculum with additional opportunities to conduct lesson study activities.

6. Cross Case Analysis

In conducting a cross-case assessment, the demonstration classroom findings were compared and contrasted to the lesson study findings in order to:

1. Identify points of commonality;
2. Identify points of difference;
3. Identify the circumstances and conditions for which it may be most appropriate for a teacher team to participate in a demonstration classroom PD experience, and similarly under which circumstances and conditions for which it may be most appropriate for a teacher team to participate in a lesson study PD experience.

What do Demonstration Classrooms and Lesson Study have in common?

The following were identified as common themes across the demonstration classroom PD and the lesson study PD models. These themes are generalized below, however, in different case studies, there would most likely be variation.

a. Use of an Inquiry Stance

Both demonstration classroom and lesson study PD experiences are forms of teacher inquiry into practice. They involve teachers thinking about the practice of others, observing the practice of others, and thinking about their own practice. This is a combination of reflection-in-action and reflection-on-action (Schon, 1983). The role of the PD facilitators is not, in either case, to direct teachers, but rather to support teachers in their learning, goal setting and implementation. In the case of demonstration classrooms, the visiting teacher team is expected to set goals and acquire effective teaching strategies that are revealed through the classroom visits. In the case of lesson study, the teacher team inquires about a specific area of concern in mathematics learning that they research and explore with one another and researchers, with resources, and with students in classrooms.

b. Classroom Context Learning

The catalyst for teacher learning is situated within the classroom context where teachers are teaching and other teachers are observing. Both DC and LS demonstrated that teachers were engaged in active learning that was context embedded. What is important here is that these shared moments of observation and teaching were considered "real"; teachers saw these lesson situations as similar and parallel to their own lesson situations. The classroom context learning became the key driver or instigator for teachers to reflect on their own practice and subsequently make refinements in their lesson planning and teaching. In observing other teachers, who were similar to themselves, teaching in classrooms similar to their own, participants had a point of common reference for their reflections, and were easily engaged in independent and collective reflective practice.

c. Lesson Orientation

For both PD programs, the technical focus was on a given lesson, whether it was a "regular" classroom lesson in a demonstration classroom, or an exploratory or public lesson in the lesson study teacher classrooms. In the demonstration classroom case study, the focus was on the structure and delivery of a three-part lesson that fostered a community of mathematics learners. In lesson study, the team focused on lesson planning, as well as observation and reflection on how the lesson functioned to bring about student understanding. The teacher teams purposefully selected an area of mathematics that students found difficult to learn and/or teachers found difficult to teach. The teacher team then tackled this problem by exploring teaching and learning situations (through exploratory lessons) to see what students were able to do and understand using higher-risk, innovative strategies. The observations of these exploratory lessons supported the refinement of the lesson to better meet student needs in the public lesson.

d. Messy Processes

Both PD models involved examining the messy nature of problem solving in messy classroom contexts. The PD model gave lesson study teachers permission to try things out, rather than using prescribed strategies deemed to be effective by texts or other sources. In observing mathematics teaching and learning in classroom contexts, the messy nature of the learning process was revealed and discussed by participants of both lesson study and demonstration classroom PD models. For example, in the demonstration classroom viewed by the Oriole Park teachers, students and the teacher were completely candid about their learning, and the lessons taught during the visits were typical of the regular classroom activities, including student absences, suspensions, varied teacher level of preparedness, and teacher willingness to try things not previously rehearsed.

The teachers of lesson study also engaged in messy planning processes; teacher team members wanted to contribute fully to the lesson planning process, and to the implementation and observation of lessons. This led to multiple ideas for approaching the same goals. For example, in Pine View High School, each teacher had suggestions to contribute in terms of how to engage students in understanding volume. The stations structure provided all with that opportunity because there were multiple parallel tasks to generate, evaluate and refine.

e. Attention to Pedagogy

Both PD models encouraged attention to specific teaching and learning strategies including the use of manipulatives and interactive whiteboards, as well as pedagogical strategies such as the use of consolidation at the end of lessons to solidify student understanding, emphasis on building a math-talk community, and teacher assessments of student understanding. For example, in the demonstration classroom, the teacher was observed letting student ideas stand in classroom discussions even when they were flawed. The teacher did this purposefully to engage students in dialogue about "what makes sense". In the lesson study activity, teachers made tremendous efforts to use the interactive whiteboard as an innovative way to build student understanding and to facilitate student communication.

f. Expansion of Collaboration

In both cases, the teachers initiated specific activities to draw in teachers beyond the PD team. For example in lesson study, the teachers at Hillside asked teachers beyond the team to conduct exploratory lessons and report back on their findings. The teachers at

Pine View expanded their team to include both elementary and secondary teachers, bridging the division gap. The visiting demonstration classroom team engaged colleagues back at their school in discussions about 3-part lessons and shared sample plans with one another.

What is different about Demonstration Classrooms compared to Lesson Study?

In order to illustrate the distinctions between the PD models as carried out in Kawartha Pine Ridge District School Board, a summary comparative chart is provided.

Table 7
Differences between Demonstration Classroom and Lesson Study Treatments

KPR Demonstration Classroom	KPR Lesson Study
a. Intentional observation of the overall classroom environment, teacher moves, and the structure of the lesson	a. Intentional and careful listening to and observing of students and examination of student work
b. May be a relatively short term commitment over several days, weeks, or SMART goal period	b. Long term teacher commitment over a full academic term, year or years
c. Teacher collaboration (co-planning) may occur amongst the teacher team attending the DC (but not necessarily with the demonstration teacher who is providing the initial lesson) where parallel lessons may be designed after the DC visit	c. Teacher collaboration (in the forms of co-planning and co-teaching) occurs amongst the lesson study teacher team in an effort to design single high quality lessons that are then implemented and observed
d. Is relatively linear in nature [although can be repeated in cylces]	d. Is relatively cyclical in nature
e. Structured with external facilitation at a district level in order to support the set-up and visits of the demonstration classroom	e. Structured with a site-based facilitation model where groups of teachers in schools can work collaboratively with limited need for external facilitation (teacher directed)

Under which circumstances and conditions might it be most appropriate to participate in a demonstration classroom PD experience?

1. Entry stage - appropriate where teachers have limited experience or are having difficulty visualizing specific strategies such as a 3-part lesson format, facilitating a math-talk learning community, or inquiry-based learning.

2. Helpful in supporting teachers who wish to form a collaborative network that focuses on instruction and learning.

3. Where there is support from PD staff (administration and facilitator) who can help to establish the host site (the demonstration classroom) and the visiting team network, facilitate visits, goal setting, lesson planning, etc.

Under which circumstances and conditions might it be most appropriate to participate in a Lesson Study PD experience?

1. Advanced stage - appropriate where teachers are attempting to advance their instruction in new directions. Involves risk taking by teachers as they plan together and observe one another teach.

2. Helpful in supporting teachers who already have a means to collaborate as a team focusing on instruction and learning (somewhat autonomously).

3. Where teachers are purposefully targeting areas of particular teaching and learning difficulty. (Content expertise is required either within the team or in the form of researcher expertise/support).

Comparing Theoretical Models to the Findings

We began by presenting two diagrams that represented the theoretical models of the PD. In returning to these now, both diagrams proved to be reasonably accurate. The two diagrams represent the process (flow and stages that occur) for each type of PD.

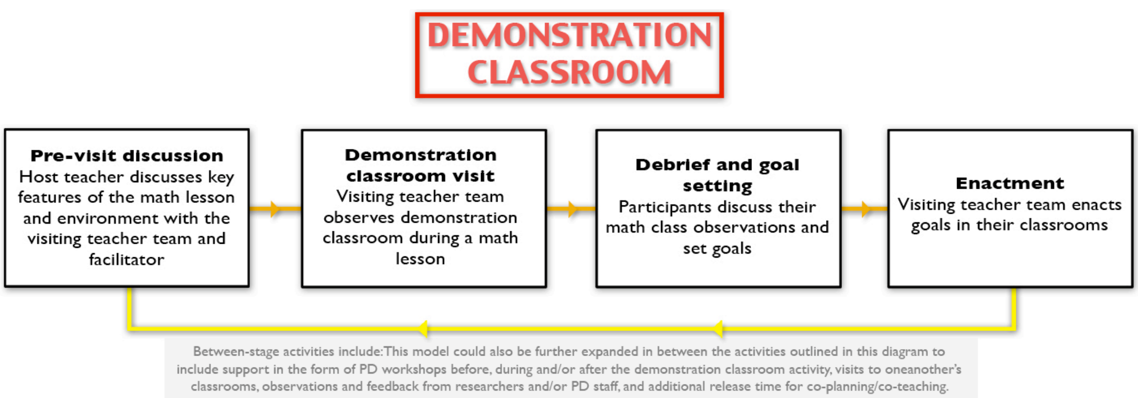

Figure 4. *Demonstration Classroom Model*

As Figure 4 illustrates, PD for demonstration classrooms can be enacted as a linear model, taking teachers through the pre-visit, the classroom visit, the post-visit and finally providing some structure for setting goals in the classroom based on observations and discussions involving the demonstration classroom. The demonstration classroom experience can end here, but the literature and this research shows how a very robust model would make these activities cyclical in nature and potentially more powerful. Ideally, goal setting (the final activity shown in Figure 4) would really be a launching point to a new cycle of activity. Teachers would use this opportunity to set goals for their own classroom implementation *and* for their own learning in the next round of demonstration classroom activity. This iterative process would provide rich opportunities for learning, as teachers would have a base of learning to drive their inquiry and implementation in the second round. This model could also be further expanded in between the activities outlined in this diagram to include support in the form of PD workshops before, during and/or after the demonstration classroom activity, visits to one another's classrooms, observations and feedback from researchers and/or PD staff, and additional release time for co-planning/co-teaching (as per Luft's work).

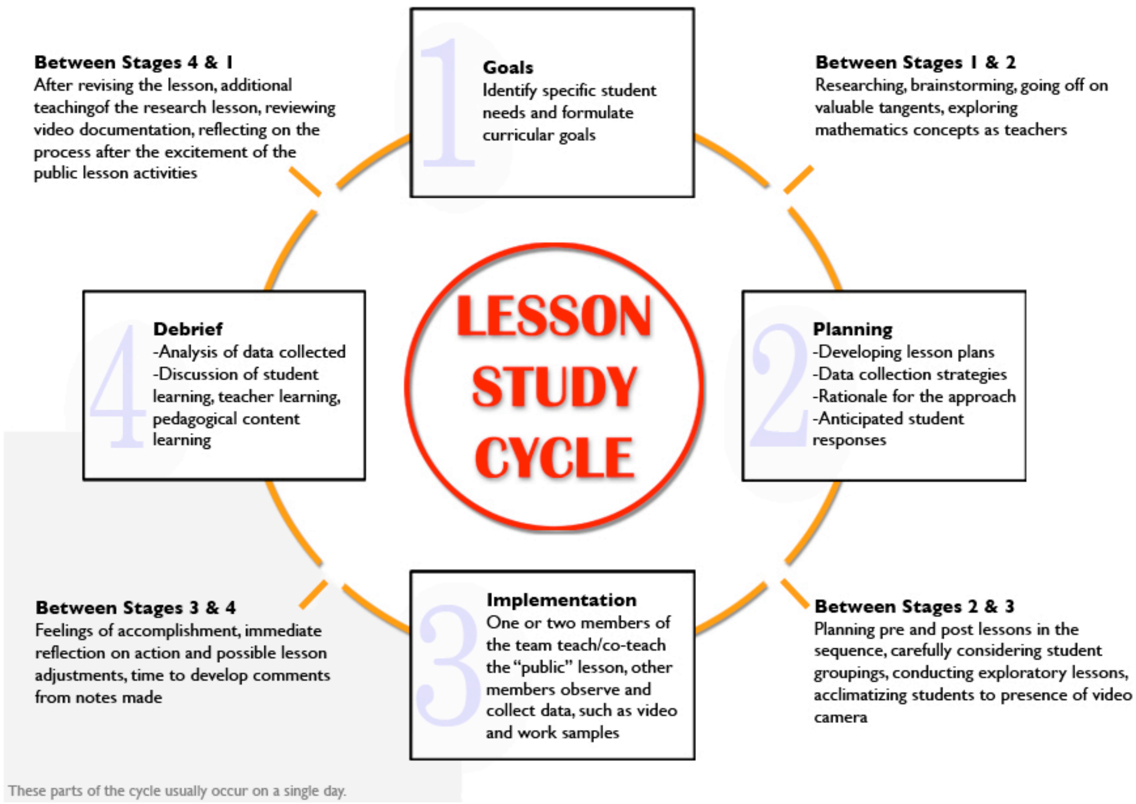

Figure 5. *Lesson Study Model*

In the case of lesson study, the Figure 5 accurately represents the process, however the emphasis in Year Two on the mechanisms and catalysts for teacher growth were of particular interest. Researchers generated a second diagram to illustrate the situated nature of the learning (in classroom contexts with students) and the mechanisms that supported teacher learning (catalysts for change).

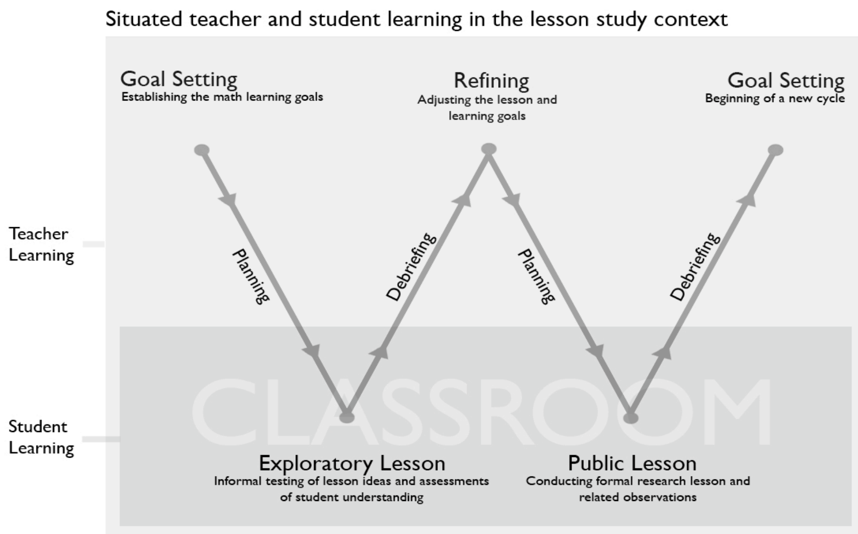

Figure 6. *Revised Model of Lesson Study*

Figure 6 shows a linear depiction of possible lesson study activity, but as with demonstration classrooms, for the maximum benefit, this model would be cyclical in nature, with goal setting in the final instance acting as a springboard to further inquiry and lesson study activity. This diagram shows both the *site* of learning for teachers and students as well as the *drivers* for change through lesson study. For students, the site of learning is primarily in the classroom, where the exploratory and public lessons take place. For teachers, learning occurs in the classroom and elsewhere, wherever the team does their collaborative work. Of paramount importance is the fact that this learning is *situated* in the classroom context, where the exploratory and public lessons place teacher learning in the familiarity of the classroom *and* act as the catalysts for change. According Lave and Wenger's (1991) seminal work, situated learning occurs within communities of practice at the site at which the learner will be performing the activity and is accordingly embedded within that context. The learning is not transmitted from one person to another, but socially co-constructed through participation as well as through mechanisms of observation and discussion. In these respects, lesson study ably demonstrates the power of situated learning and affirms that its context-embedded nature drives the learning in meaningful ways.

7. DISCUSSION SUMMARY

Professional development models vary in nature and impact, including demonstration classroom and lesson study experiences. Each has the potential to offer teachers important opportunities to collaborate and to learn from teaching colleagues in classroom contexts. In this study, teachers resoundingly reported positive growth toward the use of effective teaching practices in mathematics. These reports were confirmed by classroom observations of participating teachers in the case studies, where teachers were actively pushing to implement effective three-part lessons that were engaging for students and that promoted mathematics communication in a community of learners.

Based on analysis of the findings, it appears that demonstration classrooms offer teachers an entry point into the process of opening classroom doors to one another in collegial professional relationship building situations. Lesson study, on the other hand, is a much more elaborate process that requires significant participant commitment in terms of time, but also in terms of risk-taking as the teachers are exploring specifically challenging areas of mathematics teaching and learning in one another's classrooms.

8. RECOMMENDATIONS

1. Continue to measure the effects of demonstration classroom and lesson study activity in a rigorous on-going strategy of data collection and analysis in order to determine long-term effects for teachers and students.

2. Continue to refine the professional development models:
a) with attention to the benefits of a cyclical PD process for demonstration classrooms, where participants engage in a series of goal setting, observations, debriefs and implementation activities repeatedly, rather than once;
b) with attention to the implementation of exploratory lessons in lessons study cycles, as these were the site of substantial learning and collaboration (as identified in all data sources);
(c) with more attention to supporting teachers in the development and implementation of cognitively demanding mathematical tasks;
(d) by integrating in-service in mathematics more closely with the SMART goals of individual schools' enactment of the School Effectiveness Framework.

3. Further investigate the student achievement measures ensuring validity of tests (degree of difficulty matching) and reliability of scoring (revised rubric and further scoring reliability checks).

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APPENDIX A – Qualitative Data Sources

Lesson Study

Hillside

1. Field notes (Oct 3, 23, Nov 26, Jan 15, Mar 24, May 1, May 5)
2. Video of public lesson (Nov 26 & May 1st)
3. Written responses to ETFO prompts (May)
4. Focus group interview (Mar 24)
5. Interview and transcript with Principal (June)
6. Draft of ETFO final report (August)

Pineview

1. Public lesson video (May 5)
2. Field notes of planning, exploratory, and public (8 from Jan – June)
3. Focus group interview with teachers (June 19)

Newfeld

Norwood Secondary:
1. Exploratory lesson video (Jan 16)
2. Public lesson video (April 29)
3. Field notes of planning sessions and lessons (Dec, Jan, Feb, Mar, April)

Norwood Public:
1. Public lesson video (June 3)
2. Exploratory lesson video (May 19)
2. Field notes of planning sessions and lessons (April, May, June)

Demonstration Classroom

1. Interview with two teachers from one school (May 6)
2. Classroom observations PRE (May 14)
3. Demo Day video (May 20)
4.Classroom observations POST (June 16)
5. Post Interview with two teachers (June 16)
6. Principal interview (June 16)
7. Interview with consultant (June 18)
8. Documentation from a second demonstration classroom (for Layer 2)

APPENDIX B - Qualitative Data Analysis (Coding)

Lesson Study	**Demonstration Classrooms**
Teacher Learning (TL) About Math (TLAM) About Math Teaching (TLAMT) About Math Communication (TLMC) About Student Understanding (TLSU) Renewal (TLR)	**Teacher Learning (TL)** About Math (TLAM) About Math Teaching (TLAMT) About Math Communication (TLMC) About Student Understanding (TLSU) Renewal (TLR)
Student Learning (SL) Math (SLM) Math Communication (SLMC) Student Understanding (SLU)	**Student Learning (SL)** Math (SLM) Math Communication (SLMC) Student Understanding (SLU)
Nature of Math Communication (MC) Student-student communication (STST) Teacher-student communication (TST) Use of IWB for student communication (IWBS) Use of IWB for teacher communication (IWBT)	**Nature of Math Communication (MC)** Student-student communication (STST) Teacher-student communication (TST) Use of IWB for student communication (IWBS) Use of IWB for teacher communication (IWBT)
Lesson Study (LS) Teacher Collaboration (TC) Exploratory Lessons (EL) Anticipating student responses (AST) Listening and watching students (L/W)	**Teacher Collaboration (TC)** Risk-taking (TCR) Trust (TCT) Co-planning (TCCP) Observing one another (TCO)
	Enactment (E) Of elements of 3-part lesson (E3)

APPENDIX C – Digital Papers (Guiding Document)

Video documentation has become an integral component of data collection in educational research. Video episodes are viewed, clipped, analyzed, transcribed and analyzed again. And yet when it comes to writing up findings, researchers are typically forced to describe the visual nature of their data; the reader does not have access to the data and is unable to see the video itself, resulting in a "flattening" out on the experience of what was a lively, dynamic, and engaging process. Digital video is now emerging as a powerful engagement and portrayal tool; one that is helping teachers to connect with and improve their understandings and interpretation of their practice (Carraher et al., 2000; Pea, 2003).

In 2004, Olivero *et al.* developed a format called videopapers. A videopaper is a marriage of the traditional paper written by researchers and academics (but not exclusively so) and videotaped classroom footage of teachers and students working in real classroom situations. Combining the video with the text creates a fluid document that is more explicit than the text or video alone.

Building on Olivero's videopaper work, in an attempt to bring video-based research to life, we have generated a conceptual and virtual framework called Digital Papers. Digital Papers is a web-based tool, that allows researchers to show their findings alongside video clips, transcripts of the video clips, and conceptual models that frame their work. It is the conceptual model that drives the Digital Papers and distinguishes them. The diagrams are interactive and frame the ideas of the Digital Papers so that viewers control their experience through the diagram, navigating through a complex series of layered screens with ease. A second distinguishing feature is that our Digital Papers focus on one key concept (e.g., Engaging Students in Math Talk) or research story (e.g., Lesson Study as a PD Process).

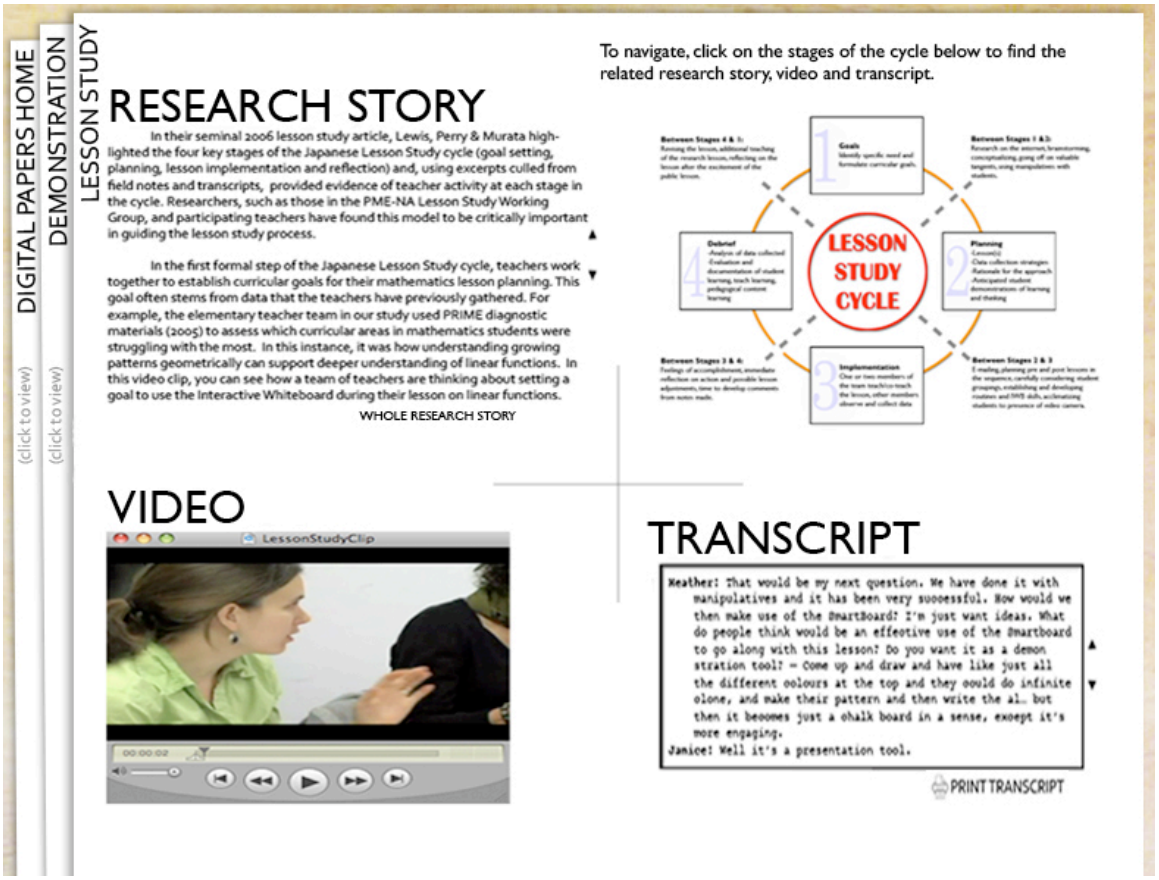

Figure 1. Sample screen shot of Digital Paper

There are five main components to each screen within the digital paper (see figure 1): a) a static title area; b) a video clip (which could be in the form of an animation or video footage in educational settings; c) a transcript of the video clip; d) a research story (which may also include question prompts for viewers and salient quotes); and, e) a framing diagram. The template allows the viewer to drive their learning, but it is guided by the diagram (e) on the right bottom corner of the template. This diagram is interactive in that it not only illustrates what the paper is about, but it also links the viewer to whichever part of the framework the viewer would like to explore.

Application to non-research projects:
Digital Papers do not have to be research-driven *per se*. The model can be used to illustrate teaching strategies, professional development models, student learning moments, teacher coaching strategies, and effective practices to name a few. We believe that Digital Papers is an excellent tool for presenting information dynamically, using multi-media to complement and illustrate ideas. In these cases, rather than a research story, there might be a different story or slide show supported by existing research but also guiding the viewer to think about his/her own practice, for example.

There are currently two types of Digital Papers in development:

a) Digital Research Papers

b) Digital Professional Learning Papers

Both types of papers are grounded in research.

The concept of the digital paper was developed by Dr. Catherine D. Bruce, an Associate Professor at Trent University's School of Education and Professional Learning, along with teacher-researchers Tara Flynn and Rich McPherson, also associated with Trent University and the Trent Math Education Research Collaborative (TMERC). The research team is collaborating with a development team at the Ontario Ministry of Education to increase capacity and production.

APPENDIX D – Math Communication Guidelines

Math-Talk Guidelines Used to Facilitate Mathematics Communication in a Community of Learners

Explain: “This is what I am thinking”; “This is my idea”; “I think __ is saying…” “I would just like to say…”

Agree with reason: “I agree because…”

Disagree with reason: “I disagree because…”

Build on: “I would like to build on that idea…”

Go beyond: “This makes me think about…”; “Another way to think about this is…”

Bruce, C. (2007). Student interaction in the math classroom: Stealing ideas or building understanding? *Research into Practice: Ontario Association of Deans of Education. Research Monograph #1 (Premier Edition),* 1-4.