SUPPORTING TEACHERS IN THEIR IMPLEMENTATION OF MATHEMATICS INSTRUCTION FOR UNDERSTANDING:
THE INTERMEDIATE MATHEMATICS TEACHERS' INQUIRY GROUP

by

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ABSTRACT

Current reform ideas in mathematics education recommend that instruction focus on teaching all students to learn and understand mathematics, and make connections within mathematics and applications of mathematics. Implementation of these ideas requires teachers to make use of teaching practice that, for most of them, is different from their previous experience in teaching mathematics. Past attempts to implement lasting change in education through the legislation of new curriculum have not proven successful. In addition, professional development opportunities that offer isolated, one-time workshops have also failed to support teachers working towards change in their teaching practice.

The Intermediate Mathematics Teachers’ Inquiry Group (IMTIG), was a professional development model, designed to support teachers as they worked with mathematics reform ideas to improve their teaching practice and hence, student learning. The format of this project incorporated recommendations from other teaching learning communities, adapted to fit our local context. The study involved the participation of seven intermediate mathematics teachers and two university participants, who all met regularly over a period of four months. Teacher learning took place in two contexts: during group meetings and in individual teachers’ classrooms.

The community of support and collaboration that developed within IMTIG was a major reason for IMTIG’s success. Participants valued the regular meetings with colleagues to discuss new ideas, and share experiences and resources. Group discussions dealt with issues related to mathematics reform ideas, and assisted teachers as they worked to adapt and implement IMTIG teaching practice in their classrooms. Upon completion of the
IMTIG project, all participants indicated their willingness to continue using teaching practice related to mathematics educational reform.

The role of the two university participants within IMTIG was to introduce new ideas to the group, to provide access to resources, and to help the group maintain a focus on the goal of improving mathematics teaching to best teach for student understanding. The two university participants in IMTIG played different roles within the group. One role was to share relevant resources and present IMTIG teaching practice, and the second role was to introduce ideas from research and theory and to encourage teacher reflection.
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GLOSSARY

The following terms are used frequently throughout this paper. The meaning of each within this project is given below as reference for the reader.

*Intermediate mathematics teachers:*

Teachers of grades five, six, and/or seven in the Sea Side School District are considered to be intermediate mathematics teachers. These teachers are trained elementary teachers who teach all subjects to one class of students; they are not mathematics specialists. They teach the upper grade levels of elementary school (kindergarten to grade seven, inclusive). Students in the Sea Side School District begin high school at the start of grade eight. This meaning is different from some other definitions of intermediate teachers in other school districts, where middle schools, with subject-specific teachers for grades six, seven, and eight, are used as a transition between elementary and high school.

*Teacher learning community:*

A teacher learning community is a group of teachers who meet regularly over a period of time to collaboratively discuss aspects of their teaching practice that are common to the group, with the aim of improving student learning.

*Teacher inquiry group:*

A teacher inquiry group is another name for a teacher learning community. It shares the same characteristics and hence has the same definition as the learning community described above.
Intermediate Mathematics Teachers' Inquiry Group (IMTIG):

IMTIG is the acronym we used to define the Intermediate Mathematics Teachers' Inquiry Group. IMTIG is a learning community of intermediate teachers who teach mathematics and who work together to analyze mathematics teaching practice and resources, modify and/or design new resources to best meet the needs of their students, test these newly developed teaching strategies in their own classrooms, and return to the group to discuss the outcome of their trials. The goal of this group is to improve their teaching practice and student learning in mathematics.

Instruction for understanding:

Hiebert and Carpenter (1992) define teaching for understanding as any type of instructional strategy that helps guide students towards recognizing relationships between pieces of information. “[U]nderstanding can be viewed as a process of making connections, or establishing relationships, either between knowledge already internally represented or between existing networks and new information” (p. 80). For the purpose of IMTIG, instruction for understanding involves the use of activities, rich problems, and projects, designed to help students make connections and build relationships between existing mathematical knowledge, other aspects of mathematics, and real-life applications.

Rich Problems:

Rich problems promote students’ deeper thinking about mathematics and/or applications of mathematics. These types of problems are not rote, and should take students a longer time to complete than more routine problems.
Problem-based mathematics instruction:

As defined by the NCTM (2000), “Problem solving means engaging in a task for which the solution method is not known in advance. In order to find a solution, students must draw on their knowledge, and through this process, they will often develop new mathematical understandings” (p. 52). Problem-based mathematics instruction, for the purpose of IMTIG, is the use of rich problems to teach mathematics. The goal of problem-based mathematics instruction is to encourage students’ mathematical thinking, problem solving, and communicating, and to lead students towards the development of their own understanding of mathematical concepts and/or applications.

Project-based mathematics instruction:

For the purpose of IMTIG, project-based mathematics instruction is the use of longer, more involved problems, called projects, to teach mathematics for understanding, and to illustrate connects between different aspects of mathematics, other subjects, and the real world. Students working on projects must solve a wide variety of parts of the larger problem using many different steps and strategies. They must effectively communicate their results, reflect on their process, and draw connections between mathematics and other subjects and/or the real world.
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This thesis is dedicated to Ian and Paul.
CHAPTER 1 – INTRODUCTION

Background and Rationale

The changing needs of society and the increasing role of technology means that citizens today need to be more mathematically literate than they have in the past (Findell, 1996; National Council of Teachers of Mathematics [NCTM], 2000). Yet results of international testing and comparisons have shown that American children score significantly lower than children from many other countries on tests of mathematics, and that the type of mathematics instruction in North America does not encourage students to truly interact with and develop a deep understanding of the subject (Ma, 1999; Stigler & Hiebert, 1999). There have been calls from many different educational organizations, researchers, and teacher groups for reform in mathematics education (Conference Board of the Mathematical Sciences [CBMS], 2001; Hiebert & Carpenter, 1992; Hiebert et al., 1996; Ma, 1999; NCTM, 2000; National Research Council [NRC], 1989; Schoenfeld, 1992, 1994; Schroeder & Lester, 1989; Simon, 1997; Stigler & Hiebert, 1999). These groups support the idea that mathematics education must change to enable all students to both learn and understand mathematics and to make connections within mathematics and between mathematics and their daily lives.

To create meaningful, lasting change in education, teachers must be at the forefront of reform efforts (Eisner, 2000; Fullan, 2001; Stigler & Hiebert, 1999). Past attempts to implement lasting change in mathematics instruction through the legislation of new curriculum have mostly failed (Cohen & Ball, 2001; Fullan, 2001). Professional development that offers isolated, one-time workshops have not proven effective in helping
teachers achieve lasting change in their teaching practice (Howley & Walli, 1999). In addition to this, the implementation of reform ideas in mathematics education will require the majority of teachers to teach in ways that they themselves have never experienced. For many teachers, their only experience with mathematics instruction is based upon the use of traditional textbooks and repetition of procedures and basic skills (Hiebert et al., 1996). Yet what reform efforts are recommending, and what research has demonstrated, is that mathematics should be taught for student understanding rather than just mastery of skills (Hiebert & Carpenter, 1992; Hiebert et al., 1996; Ma, 1999; Schoenfeld, 1992, 1994; Schroeder & Lester, 1989; Simon, 1997; Stigler & Hiebert, 1999). For teachers to be able to implement this, they themselves will need to learn new teaching strategies, including the use of rich problems and classroom discussion, to help guide students towards their own construction of mathematical knowledge (NCTM, 2000; Schoenfeld, 1994; Schroeder & Lester, 1989; Simon, 1997). However, teaching is an activity deeply embedded in our culture, and changes to beliefs and actions are often very slow to realize (Stigler & Hiebert, 1999). To successfully implement mathematics education reform ideas, a means to assist practicing teachers in their efforts to implement new teaching practice over a longer period of time must be found.

Improvements in teaching are most successful when they are developed within the context where they will be implemented. Teachers need to do their learning within their classrooms, where they will be expected to make use of new ideas (Fullan, 2001; Knight, 2002; Stigler & Hiebert, 1999). As well, since teachers are the individuals who will ultimately implement reforms in classrooms, they must be directly involved in the reform effort (Fullan, 2001). Research on teacher learning endorses the idea of collaborative work among teachers to provide opportunities for them to support each other and collectively
work towards improving student learning. Learning communities have been presented, in a variety of different forms and settings, to support teachers as they work towards improving their practice (Arbaugh, 2003; Baird & Mitchell, 1997; Borko, Mayfield, Marion, Flexer & Cumbo, 1997; Fullan, 2001; Howley & Walli, 1999; Knight, 2002; Putnam & Borko, 2000; Stigler & Hiebert, 1999; Simon, 1997).

This thesis project made use of an intermediate mathematics teacher inquiry group (IMTIG). This variation on the learning community model brought together researchers and intermediate teachers to design and implement mathematics teaching for understanding using problem and project based mathematics instruction, as suggested by Hiebert et al. (1996), the NCTM (2000), Schoenfeld (1992, 1994), and Schroeder & Lester (1989), among others. By working together to modify and design new lessons, teacher participants worked through any weaknesses they might have had in their mathematical understanding, as well as any questions that arose while learning how best to implement rich problems and/or projects in their lessons, with the support of colleagues. Teachers had the opportunity to test IMTIG lessons in their own classrooms, and then discuss the outcome of their efforts with the rest of the group at regular group meetings. These meetings provided a venue for teachers to share both their successes and failures, to gain support, and to receive suggestions on how to improve their efforts. It is hoped that future teacher inquiry groups, or learning communities, will be able to make use of the resources and experiences of IMTIG, to further improve mathematics teaching.
Researchers’ Personal Perspectives and Involvement

The Intermediate Mathematics Teachers’ Inquiry Group, or IMTIG, was a project idea created jointly by my research partner, Karen Jones, and myself. Our common goal for this project was to build a group where teachers could work together to improve their own teaching practices and hence student learning, over a period of time.

Karen is a part-time master of education (M.Ed.) student and a full-time grade six/seven, intermediate teacher, with seven years of regular teaching experience, a B.A. in history and French literature, and a B.Ed. in elementary education, both from the University of British Columbia (UBC). As an upper-elementary or intermediate teacher in the Sea Side School District, Karen teaches all subjects to her students, although mathematics has always been her passion. Karen took calculus in university “for fun” and chose to focus her M.Ed. studies on mathematics education. Karen has spent much of her seven years of teaching building a repertoire of games, activities, problems, and other resources for teaching mathematics beyond the textbook. She is particularly interested in how to decrease anxiety levels in students to better enable them to learn mathematics, and in the impact that math anxiety in teachers and parents has on student learning.

I am a full-time magistral student and a high school mathematics teacher, with six years regular teaching experience, a B.Sc. in mathematics and computer science from the University of Ottawa, and a B.Ed. in intermediate-senior (grades seven to twelve) mathematics and computer studies education from Queen’s University. All of my teaching experience has been overseas, in the Middle East and Asia, at international schools. In part due to the readily available resources and smaller class sizes in these schools, I have spent a lot of my professional time exploring ways to include more projects and problems in my
teaching practice. I have always encouraged my students to work towards understanding rather than memorizing mathematics, although I realize now that I still spent a lot of my time explaining to students rather than guiding and enabling them to create their own understandings. I returned to university to pursue a master’s degree full-time, to further expand my knowledge of mathematics education and teaching practice. These past two years of graduate studies have been a wonderful journey for me; I have had the opportunity to explore in greater depth the current reform ideas in mathematics education and am now looking forward to returning to a regular high school classroom where I can begin to implement some of these new teaching strategies.

During my first mathematics education course at UBC, Dr. Zahra Gooya, a visiting professor from Shahid Beheshty University in Iran, introduced me to two main ideas which have directly shaped the course of my thesis studies: the idea of teaching mathematics via problem solving, and the issues with non-mathematics specialists teaching mathematics courses, in particular at elementary levels. To teach mathematics for understanding using problem-solving, as suggested by Alan Schoenfeld (1992), teachers need to be confident in their mathematics. Unfortunately, a disproportionate number of elementary teachers lack the mathematical knowledge base, and some also suffer from math anxiety; these difficulties often reduce teachers’ confidence levels and can limit them to teaching mathematics in more traditional, lecture-style and rote practice manner (Tobias, 1993). After volunteering in Zahra’s mathematics course for prospective elementary teachers, and witnessing first hand their limited understanding of many basic mathematical concepts, I began to consider ways that these aspiring teachers might be able to increase their confidence and hence improve their mathematics teaching practice.
I began by examining existing research and materials about math anxiety. The works of Shelia Tobias were very influential, and I have since incorporated her idea of mathematics journal writing in my own teaching. This technique, where students do their mathematical work along side written thinking, was particularly helpful when I taught the same course that Zahra had taught for prospective elementary teachers at UBC (July 2002 to April 2003). The students who enrol in these mathematics courses, MATH 230 and MATH 335, have generally not had positive past experiences with mathematics. They only take these courses to meet the minimum requirements for application to the Faculty of Education, and most of them have put off taking the course until the last possible moment. Many of these students expressed their concerns about math, their stories of past humiliations, and their fears of failure. From my own informal observations, it seemed apparent that students’ level of anxiety decreased as their level of understanding increased. By spending more time engaged in deeper thinking about a problem, they seemed to develop greater understanding of the problem, and hence felt less anxious about it. Hence, from my own personal experience and perspective, I began to link the idea of building understanding of mathematics with decreasing anxiety and increasing confidence. I hoped that by extending this same idea to practicing teachers that they too might be able to increase their confidence and improve their teaching practice.

During this same time, I also took a course dealing with curriculum change and implementation with Dr. Linda Farr-Darling. In this class we explored ideas about reform in education, why it usually fails, and how it might be better designed to succeed. It was also during this class that Karen and I decided to do our first project together. We read and presented ideas from Stigler and Hiebert’s book, *The Teaching Gap: Best Ideas from the World’s Teachers for Improving Education in the Classroom* (1999). The concept of lesson
study appealed to both of us, and we presented a joint summary of the main ideas to our class. I also wrote a final paper for this same class, examining the NCTM's current reform efforts (2000) and considering the possibility of using lesson study as a means to help implement them. I compared the features of lesson study to Fullan's (2001) recommendations for successful educational reform and it seemed to be a viable professional development model. Also, the collaborative nature of lesson study appealed to both Karen and I as a natural way to support teachers as they worked to improve their teaching practice.

The lesson study idea eventually formed the basis of this research project. With encouragement and support from our advisor, Dr. Cynthia Nicol, Karen and I designed and implemented our own collaborative professional development group, IMTIG, and gathered data from it for my thesis and Karen's graduating paper. Karen and I each played a different role in the development and implementation of the IMTIG project. Karen was the creative person, mainly responsible for the resource package given to participants at the start of the project, and for selecting activities, problems, and projects to introduce during meetings for group discussion. As an intermediate teacher, Karen was able to offer her own experiences and ideas from a practical perspective, and was often looked upon by the group as the expert with teaching intermediate mathematics. My role was more of researcher and outside consultant. I was responsible for the ethical review and data collection necessary for the research. During meetings, I contributed questions or ideas from theory and research related to the group's discussion. Although some of my experience as a high school and post secondary instructor was relevant, and I did share it with the group, I did not feel that the participants were easily able to relate these ideas to their own classroom environments. The more important aspect of my involvement was to help guide the group's discussions
towards teaching practice and student learning by asking questions and presenting ideas. Together, Karen and I formed a strong team, with each of us meeting different but essential needs of the project.

As IMTIG progressed, I became more aware of and interested in the broader concept of teacher learning communities. Lesson study is just one example of a learning community; other examples are discussed in detail in chapter two. The general features of each of these projects include groups of individual teachers who meet regularly over a period of time to collaboratively improve their teaching practice. Our hope and plan for IMTIG was to use a learning community as a means of on-going, supportive professional development for teachers, who would engage in reform ideas and practices within the teacher group and within their own classrooms. We felt that this model would offer support to our teacher participants, to help them increase their understanding of both the mathematics and ideas involved in current reform efforts, and hence enable them to improve their teaching practice and student learning collectively over time.
Research Questions

The purpose of this project was to determine if a variation on a learning community professional development model, the Intermediate Mathematics Teacher Inquiry Group (IMTIG), was successful. The goal of IMTIG was to develop a community of support where teachers worked towards understanding and implementing mathematics reform ideas in their classrooms. It was expected that the group's discussions played an important role in providing opportunities for teachers to collectively think about how they can best teach mathematics, to help students develop a greater understanding of the subject. The research questions for this project were as follows:

1. What was the substance of teachers' discussions and what issues were important to teachers while they participated in a learning community such as IMTIG?

2. What value did teachers give IMTIG for enhancing their professional growth?

3. How did IMTIG support teachers' efforts to enhance their practice?


Research Context and Methods

This study explored the implementation of a learning community professional development model, called the Intermediate Mathematics Teacher's Inquiry Group, or IMTIG. It made use of a qualitative case study model for both data collection and analysis. This model of research was best suited for the IMTIG project because the purpose of this study was to provide an in-depth description and analysis of a particular system, and determine its meaning for the participants and its potential for future professional development efforts.

The data collection methods included video and audio recordings, questionnaires, samples of student work, and researcher field notes. The project analysis involved the transcription of all video and audio tapes, coding of the transcriptions, and deeper analysis of highlighted portions of the data. The details of this analysis can be found in chapter three.

There were two research participants involved in the project, my partner, Karen Jones and myself. We both attended every meeting as participants, collected written feedback from group members, and I was responsible for collecting and transcribing the video and audio data. A more detailed description of our involvement in this project can be found in chapter three.
Organization of the Chapters

This thesis consists of five chapters. The first chapter offers an introduction to the project and the written report. Chapter two provides the theoretical framework, while the third chapter provides the methodological framework for the study. Chapter four presents the analysis used in this thesis, consisting of four themes. The first three themes are based on group discourse (comparing basic skills and rich problems, questioning/wondering how to support and encourage students' mathematical thinking and communicating, and using group work: when and how), and the fourth theme is the value of IMTIG from the perspective of the participating teachers. Finally, chapter five presents the results and conclusions derived from this study, discusses problems that arose, and makes recommendations for similar professional development models and potential topics for further research into the use of learning communities on a wider scale.
CHAPTER 2 – LITERATURE REVIEW

Overview

There exists a need to improve mathematics education. Comparisons between teaching practice in North America and other countries, and the results of international testing, both indicate that instruction that focuses mainly on skill development does not lead to the kind of deep understanding that students need to truly become mathematically literate (Findell, 1996; Ma, 1999; NCTM, 2000; Stigler & Hiebert, 1999). Mathematics reform documents and the results of research all suggest that to teach for understanding, students need to be directly involved in their own learning (Hiebert & Carpenter, 1992; NCTM, 2000). Recommendations to achieve this in mathematics education include the use of problem solving, connections to other topics in mathematics and the real world, and the involvement of student discourse to support the development of students’ mathematical understanding (Hiebert et al., 1996; NCTM, 2000; Schoenfeld, 1994; Schroeder & Lester, 1989).

To effectively implement these kinds of reforms in mathematics education, teachers need to be directly involved (Eisner, 2000; Fullan, 2001; Stigler & Hieber, 1999). Currently, non-mathematics specialists who regularly teach elementary and middle school mathematics often do not have the confidence and/or the knowledge base to implement these kinds of reforms that require solid conceptual understanding. As well, teachers tend to teach in the ways that they themselves were taught, using more traditional skill-oriented practice (Conference Board of the Mathematical Sciences [CBMS], 2001; NCTM, 2000). To confront these obstacles, a way must be found that will involve and support teachers in their
efforts to improve their classroom teaching. "The kinds of changes envisioned by reformers require changes not only in the features of instruction but in the very goals of the teaching system" (Hiebert & Stigler, 2000, p. 7). The learning community model of professional development offers a potential means for facilitating teacher learning and hence improving student learning.

Mathematics Reform and the Need For Change

There are calls from many different groups of educators and researchers stating that mathematics education needs to be reformed (CBMS, 2001; Hiebert & Carpenter, 1992; Hiebert et al., 1996; Ma, 1999; NCTM, 2000; NRC, 1989; Schoenfeld, 1992, 1994; Schroeder & Lester, 1989; Simon, 1997; Stigler & Hiebert, 1999). Traditional school mathematics is a subject mainly focused on the mastery of skills via teacher directed repetitive practice (Findell, 1996; Hiebert et al., 1996; Simon, 1997). Critics of this type of instruction point to the fact that although students can often perform well on tests, the majority lack any understanding of the underlying mathematical concepts, and are sometimes found applying their memorized skills in inappropriate contexts (Hiebert & Carpenter, 1992; NCTM, 2000). Teachers and groups interested in mathematics education recognize that basic skills are not enough; recommendations for how to improve mathematics education began in the late 1970's in response to the "Back to the Basics" movement of the 1970's. Groups such as The National Council of Supervisors of Mathematics (NCSM), The National Council of Teachers of Mathematics (NCTM), and the National Research Council (NRC), among others, published documents recommending that students need to learn mathematics in such a way so as to understand how to perform skills as well as when to use those skills and why they make sense. Recommendations also called
for students to be able to use mathematics skills to solve problems and do a variety of tasks relevant to their lives (Findell, 1996). In the report, *Everybody Counts*, the NRC (1989) recommended that teaching methods must change from teacher-centred to student-centred, to allow students the opportunity to discover and build their own mathematical knowledge with guidance from their teachers. The NCTM published a series of three documents, the *Curriculum and Evaluation Standards for School Mathematics* in 1989, followed by the *Professional Standards for Teaching Mathematics* in 1991, and the *Assessment Standards for School Mathematics* in 1995. Together, often referred to as the *Standards*, these documents outlined a vision for the teaching and learning of mathematics, where all students learn a core set of mathematics, where the focus is on problem solving and the mathematical reasoning process, and where students are required to communicate their thinking and reasoning mathematically, orally, and in written form. Despite these and other calls for changes to mathematics teaching and the existence of documents designed to guide curriculum development, which have been available since the late 1980’s, many classrooms today still predominately make use of routine, paper-and-pencil exercises, to practice mathematics skills that are assigned by the teacher (Findell, 1996).

The weakness of the North American method of mathematics instruction was highlighted during an in depth study of videos taken of grade eight mathematics classes in three different countries, gathered during the Third International Mathematics and Science Study (TIMSS). Completed in 1999, the results of TIMSS indicate that there are significantly different teaching styles in Germany, Japan, and the United States. In their book, *The Teaching Gap*, Stigler and Hiebert (1999) focus on the differences in teaching styles between Japan and the United States. In mathematics classes in the United States, students are expected to practice a set of procedures, they obtain their solutions easily, and
if confusion occurs, the teacher’s role is to quickly intervene. American lessons are often disjointed and students are seldom aware of connections between topics within mathematics, and between mathematics and the real world. In contrast, Japanese students are expected to develop their own solution methods to learn mathematics, they struggle with difficult problems and work through them until they are confident of their solutions. Japanese teachers’ role is to provide only hints, never solutions, and to let students experience difficulties with the mathematics. They summarize students’ work, highlight mathematical significances, and illustrate connections between other topics in mathematics. The end result is clearly illustrated by the results of the TIMSS study: Japanese students have a deeper understanding of mathematics concepts and outperform American students (Stigler & Hiebert, 1999). Based on my own professional experience, I believe that Stigler and Hiebert’s description of American mathematics lessons can also describe many Canadian mathematics lessons, in spite of Canada’s stronger performance in the TIMSS study than the United States. “There is no question that the effectiveness of mathematics education in the United States and Canada can be improved substantially” (NCTM, 2000, p. 5). This concern about weakness in mathematics classroom instruction is a North American problem, not just an American one.

In the book *Knowing and Teaching Elementary Mathematics*, Ma (1999) demonstrated the differences between mathematics instruction in China, which focuses on the development of students’ understanding of mathematical concepts, and in the United States, which focuses on the development of students’ procedural skills. Ma used interview data from elementary mathematics teachers in both the United States and China, and determined that teachers in China have a significantly deeper understanding of the mathematics they are teaching than teachers in the United States. American teachers tend to
focus on isolated procedural computations and often cannot or do not explain the meaning of the underlying mathematical concepts. Chinese teachers focus more upon students' higher conceptual understanding, not just on the memorization of facts, and illustrate connections between previously learned material and real world applications. Again, on international mathematics tests, Chinese students score significantly higher than American students. Ma credits this difference both to the methods of instruction and the knowledge base of the teachers in each country; she sees these two things as closely intertwined.

Teachers with only a procedural grasp of mathematics tend to teach using procedural methods and to view student mistakes simply as problems following the prescribed algorithm. The attitude these teachers promote is one where understanding is not necessary if you can memorize the steps. On the other hand, teachers with a conceptual grasp of mathematics tend to focus more on supporting student understanding by including procedural and conceptual topics, basic mathematical principles, connections to other areas of mathematics, and relevant applications (Ma, 1999).

Japanese and Chinese mathematics teachers focus on instruction methods which encourage and support students in their efforts towards developing a clear understanding of the mathematical concepts, examining alternate solution methods, and making connections beyond each topic. These are the same ideals reflected in the most recent recommendations for mathematics education reforms. The NCTM’s latest document, *Principles and Standards for School Mathematics* (2000), is a revised and improved version of the original trilogy of NCTM *Standards* documents, again justifying and outlining guidelines for improvements to mathematics teaching.
Other researchers also focus on the need to teach students for understanding, rather than just building computational skills (Hiebert & Carpenter, 1992; Hiebert et al., 1996; Ma, 1999; Schoenfeld, 1992, 1994; Schroeder & Lester, 1989; Simon, 1997; Stigler & Hiebert, 1999). These methods of mathematics instruction appear to be working well in other countries and are therefore worth examining to help us improve our own North American teaching of mathematics.

**Teaching Mathematics For Understanding**

*Principles and Standards* calls for all students to learn “important mathematical concepts and processes with understanding” (NCTM, 2000, p. ix). The NCTM (2000) recommends that teachers choose classroom experiences and tasks that will deepen and connect students’ knowledge to both previous and new mathematical knowledge. Student learning can be enriched when students interact with each other and with their teacher; students learn to evaluate the thinking of others, defend their own thoughts and ideas, and express themselves clearly using both mathematics and language. Understanding, states the NCTM (2000), develops when students engage in problem solving and discourse.

Educators in general support the idea that to improve student learning, we must teach students to understand, critically analyze, and problem solve. As we learn more about how students learn and insist that students master more complex knowledge and develop greater capacities for problem solving, ‘teaching by telling’ is being replaced (or should be replaced) by ‘teaching for understanding’. The latter is much more difficult for teachers but much more effective for students (Hawley & Walli, 1999, p. 132).
More specifically, mathematics educators and mathematicians support the idea that students must understand the mathematical concepts, processes, and techniques they are learning (Hiebert & Carpenter, 1992; Hiebert et al., 1996; Ma, 1999; Schoenfeld, 1992, 1994; Schroeder & Lester, 1989; Simon, 1997; Stigler & Hiebert, 1999). “One of the most widely accepted ideas within the mathematics education community is the idea that students should understand mathematics” (Hiebert & Carpenter, 1992, p. 65). Hiebert and Carpenter (1992) argue that students who understand mathematics are far more likely to retain their knowledge and be able to apply it in other situations. Schoenfeld’s (1992) view is that “a curriculum based on mastering a corpus of mathematical facts and procedures is severely impoverished” (p. 335). Instead, he believes that mathematics curricula should be rich in problems and meaningful mathematics, explored from a variety of different perspectives, to lead students towards developing a deeper understanding of mathematics.

Many mathematics education academics support the use of problem solving to teach mathematics for understanding. When students are engaged in problem solving, they are doing mathematics in context, the problems are designed to be meaningful, students are motivated, and learning is transferable to other problems (Schoenfeld, 1994). Schroeder and Lester (1989) define instruction via problem solving as the use of problems to provide a purpose for learning mathematics, and, perhaps most importantly, employ problems as the primary tool for learning mathematics. As students solve problems and engage in mathematics, their understanding of mathematics increases; they are able to relate mathematical ideas to a variety of different contexts, they are able to relate problem solving to a number of different mathematical ideas, and they are able to construct relationships among mathematical ideas. Problem solving is a means by which students self-generate their own learning, resulting in a deeper understanding of mathematics and an increased
ability to solve problems (Schroeder & Lester, 1989; Simon, 1997). Simon (1997) goes further to suggest that students must do more than just engage with mathematical problems, they must also decontextualize, generalize, and abstract the ideas beyond the original problem, and participate in group discourse. Hiebert et al. (1996) recommend that problem solving be used as a basis for reform in mathematics education. They define problematizing as students engaging in reflective inquiry into why and how they solve problems. These problems can be chosen from traditional mathematics, applied mathematics, or any other area that produces problems or questions with which students can interact. It is this process of interaction and reflection that leads to students discovering new relationships and developing deeper understandings of the mathematics (Hiebert et al., 1996). Despite the extensive theorizing and research into teaching mathematics for understanding using problem solving, many students today are still memorizing mathematical facts and practicing skills from rote activities (Findell, 1996; NCTM, 2000; Simon, 1997; Stigler & Hiebert, 1999).

Of all the personal rewards in learning, a feeling of understanding is perhaps the most potent, because it is ultimately the most satisfying. Lack of understanding generates either active frustration or passive resignation. Both militate against future learning. ... Yet it might surprise some readers to learn that these feelings associated with lack of understanding are all too common for school students (Baird, 1995, p. 4).

Teachers need to learn how to implement teaching practice so that this lack of student understanding and frustration is avoided; as teachers help students develop their own understandings, their personal feelings of success will further encourage them to become active participants in their own learning (Baird, 1995).
Changes for Mathematics Teachers and Teaching

In mathematics education, the vast majority of elementary trained teachers are not mathematics specialists. As previously mentioned, Ma's (1999) research indicates that teachers' mathematical knowledge base is a strong indicator of teaching style. Teachers with a weaker or limited mathematical knowledge base tend towards more procedural instruction methods whereas teachers with a deeper, broader mathematical knowledge base are more likely to be inclined towards teaching for students' understanding. The common belief that elementary teachers can learn all the mathematics that they will need to teach mathematics by the end of their own high school diploma is now being challenged. The Conference Board of the Mathematical Sciences (CBMS, 2001) recently published a document, *The Mathematical Preparation of Teachers*, outlining the mathematics requirements needed by teachers in order to be effective teachers of mathematics at the elementary, middle, and high school levels. This document was published in response to the increased scrutiny during recent years of mathematics education, including concerns about student performance, curriculum, and teacher education. Essentially, the CBMS states that to improve mathematics teaching and student achievement, teachers at every level need to have a deep understanding of the mathematics they will be teaching, and a sense of the connections between this mathematics and future mathematics topics, in order to lead students to develop their own deep understanding of mathematical concepts. This recommendation is very similar to Ma's (1999) recommendations. The CBMS (2001) also recommend that middle school mathematics, grades six, seven, and eight, should be taught by mathematics specialists, not generalist teachers. However, in most districts in British Columbia's Lower Mainland, including Sea Side School District, generalist elementary
teachers teach grades six and seven because those grade levels are considered part of the elementary school. Students begin high school in grade eight, where specialist high school teachers, for the most part, teach them mathematics. Although reform in mathematics education is needed at every level, there is a particular need for support in these grade six and seven classes for the non-specialist mathematics teachers who are expected to teach increasingly sophisticated mathematical concepts.

A disproportionate number of North American elementary teachers were themselves not successful in mathematics and/or lack confidence in themselves as learners and teachers of mathematics. Without a solid knowledge base in mathematics, teachers cannot accurately and effectively make the mathematical connections needed to implement the types of mathematics instruction recommended in current reform efforts, including teaching mathematics for understanding (CBMS, 2001; Ma, 1999; NCTM, 2000). Even for those teachers who were successful as mathematics students and who are now confident as teachers, the mathematics content and pedagogy in current reforms is different from what most practicing teachers learned while they were in school. A deep understanding of mathematics does not necessarily imply that teachers will know how to make use of their knowledge to teach mathematics using current reform ideas.

Many teachers, having experienced more traditional classroom cultures and more conventional approaches to problem solving, will need to change their conceptions of the subject [mathematics] in fundamental ways. Working out new orientations to a subject and changing classroom practice are not easy things to do (Hiebert et al., 1996, p. 19).

Therefore it will be necessary for all practicing teachers to learn new mathematics along with the new pedagogical methods to implement mathematics teaching for understanding.
Creating change in education, however, is a complicated task. "Reform is not just putting into place the latest policy. It means changing the cultures of the classrooms, the schools, the districts, the universities, and so on" (Fullan, 2001, p. 7). Teaching is an activity deeply embedded within our culture; pre-school aged children can play at being a teacher because they have learned what society expects teachers to do. Stigler and Hiebert (1999) use the word "script" to describe the culturally determined guidelines learned implicitly by all members of a society. They believe that teaching scripts evolve slowly over long periods of time within the belief systems of a culture and therefore are not easy to change. To implement mathematics teaching for understanding and the use of problem-based mathematics instruction in all classrooms, the scripts of mathematics teachers, and hence the expectations of society at large, will have to be changed. An on-going system of professional development, designed to support teachers as they work to implement changes in their teaching practice, offers potential as a means to assist in this change (Hiebert et al., 1996; Stigler & Hiebert, 1999).

**Professional Development**

Past reform efforts have not taken into account the complex nature of reform. Schools adopted top-down reform models because they were required to do so, but then were not provided with the resources, and/or the motivation to implement them. Most often, changes were implemented on the surface only, while the actual practice of most teachers remained unchanged (Fullan, 2001). "[R]arely are interventions designed to enable the learning that educators need to do to enact the intervention. Few interveners provide substantial learning opportunities for teachers, school leaders, students, and parents" (Cohen & Ball, 2001, p. 77). Cohen and Ball (2001) criticize the most common type of educational
reform, the publication of curriculum materials. These documents are most often distributed without corresponding opportunities for teacher learning. Changes to teachers’ practice require teachers to learn new instructional strategies and this learning should be conducted using collective, not individual learning opportunities (Cohen & Ball, 2001).

Teachers are sometimes provided with professional development to help train them in the implementation of new curricula, but unfortunately, this support usually comes in the form of isolated workshops. Howley and Walli (1999) describe these workshops as private, individual activities, with information presented by experts, and state that they are often unrelated to teachers’ classroom experiences. Workshops are brief, one-time events, expected to achieve quick, visible results. Teachers have very little positive to say about the usefulness of these kinds of workshops, and in general, they have led to no significant changes in teaching practice (Howley & Walli, 1999). To effect real change in education, professional development needs to be continual and needs to involve groups of teachers as learners (Knight, 2002).

To change education means to change beliefs, teaching styles, and materials, not just curriculum documents. This type of change “can come about only through a process of personal development in a social context” (Fullan, 2001, p. 124, emphasis in original). Eisner (2000) suggests that teachers are central to the improvement of teaching. He warns that major or radical changes to teaching practice will require teachers to adapt in ways that they may not be able to without guidance and support. Eisner recommends that teachers be encouraged to work with each other, to provide feedback to each other about their teaching, and that professional development for teachers needs to become a more integrated, on-going part of schools. Fullan (2001) emphasizes the need for teachers to participate in professional
development activities within group settings, to encourage them to discuss the meaning of change in their personal context, and to work through the process of change collaboratively. He uses the term "professional learning community" to describe such a group of teachers who meet regularly and work together to continuously improve their teaching practice (Fullan, 2001).

Howley and Walli (1999) claim there is an "unprecedented consensus" among researchers and policy makers that one of the best ways to increase the knowledge and skills of teachers is to provide teachers with "collegial opportunities" to learn, which are linked to improving student learning (p. 127). Mitchell (1995) agrees: "Teaching is an isolated profession. Our system needs to assist innovative teachers to teach others" (p. 25). This new direction supports the use of professional development as a shared, public experience, involving sustained interaction between colleagues regarding issues directly related to classroom and school concerns. New models of professional development involve active teacher participation, emphasise the improvement of students learning, link the practical to its theoretical base, and expect that change will take place slowly, over a longer period of time (Baird & Mitchell, 1997; Baird & Northfield, 1995; Hiebert & Stigler, 2000; Howley & Walli, 1999; Knight, 2002). In addition, Howley and Walli (1999) state that increasing knowledge alone will not effect change; beliefs are also an important part of improving teaching practice:

Professional development must engage teachers' beliefs, experiences and habits. ... [B]eliefs are difficult to change. Teachers must experience different types of learning themselves, spend time adapting their instruction, and see positive results in their students (p. 143).
Teachers need time to design and practice improvements to teaching practice, as well as to discuss outcomes and obstacles with colleagues. Effective professional development must incorporate continuous learning in a collaborative environment into the current structure of schools, making them learning organizations for all, students, teachers and administrators alike (Fullan, 2001; Howley & Walli, 1999; Knight, 2002; Simon, 1997).

**Learning Communities**

The concept of the learning community has been suggested by a number of different researchers. The central idea, which appears to be common to the many different forms this idea has taken, is that a group of individuals meets regularly over a period of time to collaboratively improve professional practice, as is done in many other professional fields. Simon (1997) suggests that teacher improvement needs to be ongoing, and that just as students must engage in mathematics to understand it, teachers must engage in the development of successful teaching practice. He supports the idea of a community of learners who engage collectively in an inquiry process, working towards improving their teaching practice (Simon, 1997). Putnam and Borko (2000) recommend the establishment of what they call discourse communities. These communities of teacher learners can take three different forms, depending on the goals for teacher learning; they can be intertwined with teachers' ongoing practice, they can be separate from teachers' practice, or they can involve a combination of the two. Putnam and Borko refer to one particular professional development model that combined workshops, which introduced theoretical and research-based ideas, with on-going support, which helped teachers integrate the new ideas into their teaching practice. They recommend that this may be the best combination of experiences to help teachers change their previous conceptions of mathematics teaching.
It may be that a combination of approaches, situated in a variety of contexts, holds the best promise for fostering powerful, multidimensional changes in teachers’ thinking and practices. Further research is needed to better understand the complex dynamics of these multifaceted approaches to teacher learning (Putnam & Borko, 2000, p. 7).

This, in part, is what the IMTIG project has attempted to do, explore the combined use of a collaborative teacher learning community with individual teacher learning in their own classrooms.

**Lesson Study**

The Japanese *kounaikenshuu* or “lesson study”, as described by Stigler and Hiebert (1999), offers a potential learning community model for teachers to work collaboratively to improve their teaching practice over time. Teachers in Japan are directly involved in the process of improving teaching, working together in small groups to study and improve student learning. Teachers in each lesson study group choose a topic and develop a new or improve upon an existing lesson. They conduct research to discover how others have taught the same topic in the past and to become aware of what researchers have to say about their topic. The lesson study group designs, tests, modifies, and retests a research lesson based upon their work. Teachers dedicate a considerable amount of time each month towards the development of these research lessons, and the process is extremely valued by all Japanese teachers. Every teacher involved in a lesson study group takes ownership for the developed lesson; there is no competition between teachers. Criticism is taken towards the project, not individuals, and is used to constructively improve the research lesson. All group members share in the successes and failures of their collective attempts.
Although lesson study groups focus intently on only a few lessons a year, teacher participants learn additional general knowledge and skills, which helps them teach their other lessons more effectively as well. The sharing of research lessons at the end of each project is another, more public, way for the benefits acquired by each lesson study group to be shared with other teachers. Lesson study groups write a report or a book, sometimes inviting teachers from other schools to attend their final presentation of the research lesson. One of the main goals of kounaikenshuu or lesson study, is to contribute to the professional knowledge base, to allow the gains made by each group to be shared with all teachers and thereby to continuously improve teaching practice over time (Hiebert & Stigler, 2000; Stigler & Hiebert, 1999).

While teachers are producing shareable work, they are engaged in exactly the kind of learning that they need to become more effective teachers. They must learn more about the subject, about their students’ thinking, about alternative pedagogies. The lesson study process assumes this kind of learning and offers opportunities to learn through collaboration with and observation of colleagues, as well as time for study and reflection (Hiebert & Stigler, 2000, p. 12).

Teaching is a cultural activity; therefore professional development that works in one culture will likely not be directly transferable to another culture. Stigler and Hiebert (1999) therefore recommend some of the ideas from the Japanese lesson study model that may be used in North American professional developments efforts.

- The goal of reform must be to improve student learning and therefore classroom teaching. The focus must be on teaching, not individual teachers. In lesson study this is accomplished by focusing on the research lesson.
- Improvements to teaching must be made by teachers, in context. In lesson study, this is accomplished with the teacher-lead lesson study group working to improve teaching practice within their own classrooms.

- Improvements made must be collected and shared to ensure they are not lost and to allow teaching practice to continually improve over time. In lesson study, this is accomplished with the sharing of the results of the research lesson with other teachers, and sometimes with the publication of materials for a wider audience.

Stigler and Hiebert (1999) warn that this type of change will not be easy because it involves a change in school culture, and it can only take place in small increments over a longer period of time. Teachers, students, parents, administrators, and politicians will need to be supportive and patient if they are serious about creating lasting change in education.

An implementation of lesson study in the United States has been attempted and recommendations from this trial study are insightful. Fernandez, Cannon, and Chokshi (2003) implemented a lesson study project in an urban public school in New Jersey. They involved sixteen teachers and administrators from an American public school, as well as a dozen Japanese teachers from a Japanese school in Connecticut, who acted as lesson study coaches for the American teachers. The results of this study strongly indicate that there are “substantial challenges that must be overcome” (p. 181) to successfully implement the lesson study model in the United States. The teachers in this lesson study group had significant difficulties becoming teacher-researchers; even by the end of the project, teacher participants had not completed this transition. Fernandez et al. (2003) recommend that teachers who wish to engage in lesson study need to learn how to generate important questions about their practice, design lessons to answer these questions, and look for
evidence to determine how effective their lessons are at answering these questions. Most importantly, teachers need to develop an attitude towards teaching, where they are prepared and willing to take control of their own learning. The authors also recommend that teachers who engage in lesson study must be supported adequately for the process to be successful. The American teachers in this project were not accustomed to the role of teacher-researcher; providing them with a lesson study coach who helped push their thinking in rich directions was a necessity. The results of this project indicate that the limited gains that were made by the American teachers would likely not have happened had certain perspectives not been raised for discussion by the Japanese lesson study coaches (Fernandez et al., 2003).

Fernandez et al. (2003) point out that their recommendations for teachers who wish to participate in lesson study are in line with current reform recommendations for educators: Teachers need to become more reflective in their practice, design well-connected educational opportunities for students, and move towards more student-centred instruction. They conclude that although simply participating in lesson study does not provide a means for implementing current reform ideas, perhaps the effort required to achieve a successful lesson study implementation will provide a process by which some reform objectives can be attained.

Lesson study unites the examination of practice with commonly viewed features of quality teacher learning to create a well-defined and structured process. In addition, lesson study incorporates a number of activities we believe are useful for teachers to engage in, such as the examination of student work, the analysis of curriculum materials, and reflective writing. ... [L]esson study work ... seems to provide a comfortable forum for teachers to tackle challenging ideas about their practice and the content they teach (Fernandez et al., 2003, p. 182).
Lesson study offers much potential as a means for supporting educational reform. We adopted a number of features from the lesson study model when designing IMTIG, including the collaborative, regular group meetings, the focus on improving student learning, and the involvement of university participants or coaches, to offer new ideas and ask questions to help maintain the group's focus on its goals. Although lesson study was the original idea that inspired us to design IMTIG, we decided that aspects of it were not suited to our particular situation. Lesson study focuses on the research and development of one lesson. This goal of improving teaching practice one lesson at a time is a good one, and it has proven successful in Japan. Yet teachers in North America are not accustomed to attempts at change that are designed to occur at such a slow pace. Fernandez et al. (2003) noted that their American teacher participants found it difficult to become teacher researchers. This might possibly be due to the limitation of the project to the development of a single lesson. For IMTIG, we decided that it would be more effective to focus on the broader idea of helping teachers develop better understandings of current reform ideas, and encouraging them to interact with more than one lesson idea throughout the project to help accomplish this. We felt that teachers might be more likely to spend time reflecting on their practice if they could take new ideas back to their classrooms on a regular basis, try them out, and see more immediate results of their attempts at improving their teaching practice. Then, teachers could continue to work through other new ideas, repeating this process of discussion, implementation, discussion, and so on, while at the same time, becoming more aware of and hopefully developing a better understanding of mathematics reform ideas.
Project for Enhancing Effective Learning – PEEL

Another project, which has incorporated the idea of learning communities, is the Project for Enhancing Effective Learning (PEEL) that originated in Australia in 1985. The initiators of the project, Baird and Mitchell, intended it to help teachers improve student learning in response to societal changes, ineffective student learning, and the growing acceptance that ability is learnable rather than innate. The teachers, from a wide variety of high school subject areas, who volunteered to participate in the project all wanted to improve their teaching practice and their students’ learning, and were generally attracted to the project by the prospect of professional development. PEEL’s challenges were to enhance students’ knowledge about learning, increase students’ awareness of their own learning, and help students gain control over this learning. In other words, PEEL’s central goal was to improve students’ metacognition. PEEL incorporated the use of collaborative action research, to involve teachers both as informed participants and researchers in the project. The general structure of PEEL involved teachers meeting regularly as a group along with one or more non-teaching participants (usually academic researchers). Teachers would take ideas generated from the group back to their classrooms to implement; the group recognized that fellow colleagues could be and were a rich source of creative ideas. During following meetings, teachers would share observations, outcomes, and ideas from their classroom experiences with the rest of the group. Teachers assumed control over their own classroom research, designing and altering new teaching strategies, in line with the PEEL objectives, to meet the needs of their individual classrooms. Within the group setting, teachers openly shared both their successes and failures, without judgement, and with trust.
and respect for each other. These regular group meetings, or the learning community that evolved, proved to be one of the fundamental cornerstones of the PEEL project.

The personal nature of change means that different individuals will develop at different rates and in different directions. One of the reasons why the regular staff meetings proved to be essential for the survival of PEEL was that they helped accommodate and structure this diversity. They provided a forum for discussion, reflection and evaluation. They also provided for advice, reassurance and reward. ... The stimulation and sharing of ideas which accrued from participation in group meetings was crucial for group action-research (Baird & Mitchell, 1997, p. 218-219).

The changes that PEEL sought to promote in student learning also required shifts in teachers' behaviours, attitudes, and practice. The PEEL organizers recognized that such changes would be slow and would need regular, continual support if they were to occur. During the study, it was observed that the teachers who decided to withdraw from the project were also those teachers who were unable to attend the largest number of group meetings. “Between 1985 and 1989 there was no example of a teacher who joined PEEL and made any progress without attending meetings reasonably regularly” (Mitchell, 1995, p. 25). For those teachers who did demonstrate change, this change was gradual, and came about only after they had experienced some of the PEEL ideas successfully in their own classrooms. The PEEL researchers concluded that “personal experience generally precedes changes in attitudes, conceptions and behaviours” (Baird & Mitchell, 1997, p. 216). Overall, the project was and still is a success. It has now grown to include more teachers and more schools in Australia and several countries around the world, including Canada. The PEEL
project’s most important successes are not only in improved student learning, but also in the commitment of PEEL teachers to focus on continuously improving student learning.

The outcomes of the PEEL project are all very positive and work towards implementing lasting change in education. Many of the features of the PEEL project were also included in our IMTIG project, including the collaborative nature of the teacher group, the regular group meetings separated by teachers implementing new ideas in their classrooms, and the involvement of university participants to help guide the group. However, when we were designing IMTIG, we recognized that there are particular aspects of individual subjects’ reform ideas that need special attention, and within a mixed subject group like PEEL, these would not receive an adequate amount of consideration. In mathematics reform and within IMTIG, there is a push for students to develop understanding via interaction with mathematics through rich problems and projects. For example, teachers need to learn how to select and implement problems that guide students towards developing their own understanding of desired mathematical concepts. This issue is not one that would be of direct interest to teachers of other subjects. We also considered that teachers of very different grade levels also have very different content and concerns; for example a teacher of grade one or two must focus on very different mathematics and teaching practice than a teacher of grade nine or ten. Therefore, we designed IMTIG to be a learning community dedicated to improving mathematics instruction for intermediate teachers.

Teacher Study Group

Another project, which has incorporated similar ideas as PEEL, was based in an American high school mathematics department. Seven mathematics teachers received
funding from the Toyota Time Grant to support their efforts to develop and implement a new student-centred, inquiry-based geometry curriculum. They recognized that their desired outcome would require new teaching practices and therefore teacher learning, so they approached a researcher at a nearby university for advice, and collectively, they designed the Toyota Time Study Group. This group met every two weeks for about six months; release time was paid covered by their grant thereby enabling most of the group meetings to occur during the teachers’ regular work hours. Arbaugh, the university researcher, who was also a participant in the group, provided readings and information about current theories and research, asked probing questions, and encouraged teachers to reflect on their experiences. The group engaged both in activities and discussions during their meetings. Some of the activities were subsequently tested in teachers’ classes and discussed further during later meetings (Arbaugh, 2003).

Arbaugh (2003) concludes that this study group enabled teachers to think more deeply about teaching and learning in ways that they would not have done without the study group structure. “[A]ll of the teachers in this study group came to appreciate how participating allowed them the opportunity to engage in the learning process through building their knowledge base as well as being afforded the time to reflect on their learning and practice” (Arbaugh, 2003, p. 152). The author also suggests that her involvement, as researcher/participant, may have helped to play a role in the teachers’ learning and reflecting that occurred throughout the project. Arbaugh concludes that this opportunity for teachers’ regular collaboration with their peers was the most useful aspect of the study group, and she recommends the use of “study groups as a viable form of professional development for in-service teachers” (Arbaugh, 2003, p. 159).
There were corresponding features between the Toyota Time Study Group and our IMTIG project. Both projects included regular, collaborative group meetings with single-subject teachers, involved discussions about new ideas and activities recently tested in teachers' classrooms, and were guided by university participants. However, the time and support available to the Toyota Time Study Group was ideal but unfortunately not available to IMTIG in the local political climate of British Columbia. The education system in the province was, and still is, facing major cutbacks in education. We recognized that it would be much easier to recruit teachers to participate in a learning community if the group had access to sufficient time and money to enable all the necessary work to take place inside teachers' regular working hours. However, despite the support that IMTIG received from the local school district and the funding it received from UBC, we were not able to pay for release time for our IMTIG participants, nor could we offer them financial incentives to attend meetings outside of their regular school hours. Therefore, when we designed the project, we recognized that we would need to recruit teachers only from those who were willing to dedicate additional time and effort to the project. At the time that we began looking for participants, in June 2002, the local teachers' union was in the midst of a major labour dispute with the provincial government. Teachers had been involved in a work to rule program for most of the 2001-2002 school year, which included the elimination of all extra curricular activities. It is therefore no wonder that only seven teachers responded to our invitation to join IMTIG. All seven volunteers were invited to participate, and they came from five different schools. One advantage of the funding available to the Toyota Time Study Group members was that they were all from the same school and were therefore able to meet and talk informally during their regular workdays, outside of group meetings. Due to the reality of our local situation, this format was not possible for the IMTIG group.
University of Colorado (CU) Assessment Project

The CU Assessment Project was a learning community designed to help teachers bring their mathematics and literacy assessment practices in line with current educational reform efforts. The project consisted of a yearlong series of weekly workshops for third-grade teachers in three different schools in Colorado. The workshops involved teachers experimenting with and discussing activities distributed by the researchers, and participating in open-ended discussions about issues that arose as teachers tried implementing some of these activities in their own classrooms (Borko, Mayfield, Marion, Flexer & Cumbo, 1997).

Results from the CU Assessment Project indicate that all the teachers who participated in the workshops made changes to their assessment practices. Borko et al. (1997) concluded that conducting professional development within the actual teaching and learning context of the teachers helped them to change their practice. “One particular effective version of situated learning occurred when teachers discussed ideas in a workshop session, attempted to implement the ideas in their classrooms, and then reflected or otherwise built upon their experiences in subsequent workshop sessions” (Borko et al., 1997, p. 267). They also concluded that the social nature of the workshops encouraged collaboration among teachers and supported the social construction of new ideas and practice for the entire group. Borko et al. felt that the researchers played an important role in this by supporting the teachers with new ideas and materials, and by encouraging deeper discussions and reflections during workshop meetings. They warn, however, that teacher beliefs are strong influences on how teachers will perceive new ideas; some of the CU Assessment Project teachers adopted new practices that were incompatible with the project goals because their beliefs on the matter where also not in line with the project goals. Borko
et al. also warn that time is a major obstacle that needs to be dealt with if teachers are to be expected to implement reform efforts in their classrooms. They recommend that “if new reform efforts are to succeed ... teachers need time and opportunity during the school day for meeting with university researchers, conferring with colleagues, experimenting with new techniques, and reflecting on their practice” (Borko et al., 1997, p. 276).

The results from the CU Assessment project were positive, and our IMTIG project incorporated a number of the same learning community characteristics. These included the collaborative, regular meetings with teachers and university participants, and the discussion of new ideas both before and after implementation of these same ideas in teachers’ classrooms. The recommendation of Borko et al. (1997) that teachers need time during the school day to participate in reform activities is something that we were not able to include in our IMTIG project design. Once again, the time and support available to the CU Assessment Project was not a reality for IMTIG, therefore our teacher participants needed to be willing to donate their own time and energy outside of their regular work hours. This requirement meant that the teachers who volunteered for our project were outstanding and dedicated, but it also meant that there were many good teachers who were not able to participate due to other commitments and time pressures.

**Team-Based Schooling**

Not all learning community projects have been successful. Supovitz (2002) researched the Cincinnati Public Schools (CPS) team-based schooling reform effort from 1997 to 2000. The CPS introduced team-based schooling ideas to their district and provided incentives for individual schools to join the effort. Once involved, schools reorganized to enable groups of teachers to work together; they were in charge of developing instructional
strategies to improve the achievement of groups of students, for whom they were responsible over a number of years. Teams focused on the district's goals and collaboration among the team members and parents. Teams were given more control over their budgets and scheduling and were entitled to extra release days for professional development (Supovitz, 2002).

Although a clear structure was put into place in the Cincinnati Public Schools for learning communities to develop, and Supovitz (2002) did conclude that team-based schooling in CPS had a clear effect on how involved teachers felt within the school culture, it did not have an impact on instruction or on student learning (as measured by standardized tests). The creation of teams of teachers in CPS was insufficient to generate change in teaching practice; the project concluded that structure alone does not support reform. Although teachers felt positive about the teacher communities that developed, they reported that the majority of their meetings were spent performing tasks and completing paperwork for the district or school administration. Teams had limited access to models or experiences that could have demonstrated for them what was needed to build a teacher community focused on improving student learning. "Continuous well-ordered engagement in the ways that instructional strategies mix with curriculum to produce increasingly higher quality student work ... does not develop organically but needs to be taught, modeled, and nurtured through ongoing, content-based, localized professional development" (Supovitz, 2002, p. 1616). In addition to the team-based schooling project, the Cincinnati Public Schools were also simultaneously involved in several other reform efforts and underwent a superintendent change during the project. Fullan (2001) states that each of these stressors alone can be a reason why reform efforts can fail. Supovitz (2002) concludes that despite the shortcomings of CPS's experience, educational reforms involving instructional
communities still have value. He lists three attributes that he presents as necessary for a learning community to develop that is focused on improving instruction and student learning:

- Communities must prepare for instruction collaboratively, taking advantage of extra meeting time to learn from the group.
- Community members must teach and be taught by other group members, and the environment of the group must support this kind of sharing.
- Communities must remain flexible and take advantage of opportunities to regroup students where it is in the students' best interest to work with another teacher or student group within the community.

All of these attributes must be centred on the common goal of improving student learning. "These kinds of practices are more than just changes in the tasks that teachers perform; they are transformations in the way teachers engage in their work and with each other around instruction" (Supovitz, 2002, p. 1617).

In addition to the criticisms raised by Supovitz (2002), the CPS teams did not include a university participant or a coach, who could have assisted teachers as they learned how to build a teacher learning community focused on improving teacher practice and student learning. The results of this are clear; teachers alone were unable to maintain their own focus on the goals of the project, instead they responded to other, more immediate pressures. For our IMTIG project, we included two university participants to help guide our teacher learning community and to help maintain focus on its goals of improving teaching practice.
Summary

Mathematics instruction for student understanding has been shown to be a more effective way of teaching students than the more traditional lecture or demonstration style. Success with teaching for understanding in other countries, and results of current research, both lend demonstrate the value of employing a more student-centred, problem-solving approach to teaching mathematics. Yet despite the existence of literature and documents recommending changes to mathematics education, many teachers are still using the more traditional, skill-oriented type of mathematics instruction that they themselves experienced as students.

To bring about lasting change in education, teachers must be directly involved in learning about and improving their classroom teaching. The learning community model offers great potential to help teachers improve student learning. Successful characteristics of the learning communities described above, or recommendations made by researchers for how to build a successful learning community include:

- Creation of a collaborative and supportive, environment for teacher learning (Arbaugh, 2003; Baird & Mitchell, 1997; Borko et al., 1997; Cohen & Ball, 2001; Fernandez et al., 2003; Fullan, 2001; Howley & Walli, 1999; Knight, 2002; Simon, 1997; Supovitz, 2002).
- Focus on improving student learning (Fernandez et al., 2003; Stigler & Hiebert, 1999).
- Attendance at regular group meetings over a longer period of time (Arbaugh, 2003; Baird & Mitchell, 1997; Borko et al., 1997; Fernandez et al., 2003).
• Expectation that change will occur slowly (Baird & Mitchell, 1997; Baird & Northfield, 1995; Hiebert & Stigler, 2000; Howley & Walli, 1999; Knight, 2002).

• Inclusion of university participants or coaches, to provide teachers with access to theory and current research, and to help encourage teacher reflection (Arbaugh, 2003; Baird & Mitchell, 1997; Borko et al., 1997; Fernandez et al., 2003).

• Trial of suggested or developed ideas in teachers’ own classrooms, followed by sharing of results with the rest of the group (Arbaugh, 2003; Baird & Mitchell, 1997; Borko et al., 1997; Putnam & Borko, 2000).

The design of our IMTIG project included aspects of all of these characteristics. We hoped that if it were a successful learning community, focused on mathematics, it would enable teachers to examine mathematical concepts and teaching strategies in depth with the support of other teachers before presenting them to their classes. Teachers would be able to share their successes and concerns through discussion with other professionals going through the same challenges in a supportive, familiar environment. By sharing the results of their hard work, teachers would be able to improve upon lessons rather than beginning from scratch each time, thereby allowing the teaching profession as a whole to improve over time. With the external support of the researchers or university participants, teachers would gain access to relevant ideas and research in education and encouragement to reflect further on their learning process. By continuing to work within a successful learning community over a longer period of time, teachers would gradually begin to make changes in practice and to improve student learning.
CHAPTER 3 – RESEARCH METHODOLOGY

Design

This study explored the use of a teacher inquiry group, or learning community, to support intermediate mathematics teachers in their efforts to implement teaching strategies which lead to greater student understanding of mathematics. The research design used for this project was based upon the case study design; it involved the qualitative examination, description, and evaluation of a bounded system, the Intermediate Mathematics Teachers’ Inquiry Group (IMTIG), to gain a deeper understanding of the inquiry group and its meaning for the teacher participants. A qualitative case study design offered methods and techniques that enabled the researchers to pursue answers to the research questions and hence was chosen as the best means for investigation.

"[C]ase study research in education seeks to understand specific issues and problems of practice" (Merriam, 1988, p. 23). IMTIG was a specific innovation, designed to help improve intermediate mathematics teachers’ practice. "[Case study research] has proved particularly useful for studying innovations, for evaluating programs, and for informing policy" (Merriam, 1988, p. 33). The central issue explored in this study was the inquiry group itself, to determine if this learning community type of on-going professional development assisted teachers in their implementation of activities, rich problems, and projects in their mathematics teaching. This type of teaching practice has been shown to help students develop deeper understandings of mathematical concepts (Hiebert et al., 1996; Schoenfeld, 1994; Schroeder & Lester, 1989).
The data collected and data collection methods used for this study were all of a qualitative nature, designed to help focus the study on the value of the process of teachers' participation in the inquiry group. Data collection methods included audio and video recordings of loosely guided group meetings and open-ended interview questions, written responses to open-ended questions on questionnaires, and samples of student work generated in response to teacher participants' trial lessons. In all the audio and video taped data, an interaction between the researchers and participants was necessary to enable to researchers to respond to ideas, comments, and questions generated by the teacher participants during the group meetings and the interview. All observations and interactions between participants and researchers took place in an educational setting.

Data analysis for this study involved the transcription of all video or audio data concurrently with a first analysis of general categories, main themes, and deeper group discussions. Researcher notes were made alongside the transcriptions about these initial ideas. Following the transcription of all the data, an exhaustive summary of possible themes from the data was made, and finally from this list, four themes that reoccurred frequently were selected for deeper analysis. Relevant sections of the transcripts were utilized to support the major themes and additional quotations were chosen from the individual interview and questionnaires.

The case study model enabled us to conduct a deeper analysis of a collaborative professional development structure, IMTIG, and to offer insight into the possible value of such a model for future use with practicing teachers. However, researcher bias should be considered when interpreting the results of this study as the researchers were also active participants in the project and therefore their interpretations of the events may be influenced.
by their close involvement with the participants and with the project. Although the nature of any qualitative project limits the direct transferability of results to other structures in different settings and with different participants, it is expected that readers of this study will still be able to make use of the results of IMTIG to decide what aspects of this learning community may or may not apply to their own local settings.

Please note that all names, with the exception of the researchers and faculty at UBC, have been changed in this report to protect the anonymity of the participants, schools, and the school district involved in this study. Approval for this project was obtained from both the UBC Behavioural Research Ethics Board (see appendix N) and the school district (see appendix O) prior to commencement of this study.

**Development of IMTIG**

Once Karen and I had made a commitment to work together to design, implement, and study the outcome of a learning community, we spent a considerable amount of time discussing ideas and deciding on the characteristics and organization of the group.

We first decided to focus the group on intermediate mathematics teachers in the Sea Side School District. These teachers are trained elementary teachers, therefore they are not subject specialists, as in some other districts where middle schools are in use. Yet, the material taught at the intermediate level is not trivial; the CBMS (2001) recommend that mathematics specialist teachers teach students at these levels. Since this is not possible in the Sea Side School District, we decided to focus our efforts on assisting these teachers. We chose to define intermediate as grades five, six, and seven, as these are the three upper-most grade levels in the Sea Side district’s elementary schools; starting in grade eight, students
attend high school. In addition, we chose to focus our studies on the Sea Side School District because my research partner, Karen, is a teacher in this district. Therefore we were able to make use of her contacts and her classroom to help with our study.

We knew from our reading about lesson study that to be successful, IMTIG must involve an on-going, collaborative form of professional development. We decided we would recruit up to eight volunteers and meet regularly with them over a period of four months. The regular meetings were necessary for the group to build a sense of community with each other, and to enable the on-going collaborative work to take place. The project was limited to four months due to the nature of our own studies; we both originally planned to complete our master’s work by the end of the spring, 2003, and therefore needed our data collection to be finished by early January to allow us the time to analyse and write our respective papers.

We decided not to focus our meetings on the lesson study idea of developing a single research lesson; instead we introduced and discussed a variety of ideas and teaching practices that were intended to help teachers improve their mathematics teaching for student understanding. The teachers we recruited were from different grade levels, even though they were all intermediate teachers, and we decided that it was not likely that we would be able to find a single lesson that would be directly applicable to every participant’s class without alterations. We also thought that teachers would be more likely to be interested in the project if they were given the opportunity to explore and develop a wider variety of teaching ideas. Since attendance at most or all group meetings was essential for the group’s development of a supportive community, we felt we needed to consider what would best motivate teachers to want to attend and be active participants in IMTIG.
We also designed our project to strongly encourage teachers to implement a selected number of the activities, problems, and projects that we discussed as a group during meetings in their classrooms before the following group meeting. We recognized that for teachers to learn how best to design and implement reform lessons in their classrooms, at least some of their learning must take place in their classroom contexts. Many researchers of teacher learning support this idea (Fullan, 2001; Putnam & Borko, 2000). Therefore, during each IMTIG meeting, we debriefed teachers’ experiences with the new lessons they had implemented from the previous meeting, then following a short break, we tried and discussed new ideas for lessons with the group, and agreed upon a few of these for participants to try with their classes before the following meeting.

We recognized that it would be impossible to deal with every component of the intermediate mathematics curriculum during one project. After considering many topics, we decided to focus our work on number theory, as this topic is central to all grades five, six, and seven curricula. Karen collected the majority of the teaching materials and resources we needed, and we then decided to break the materials into three broad groups: activities, rich problems, and projects. Each of these serves a different purpose when teaching students for understanding. We decided that activity-based materials would involve both games and short activities, designed to raise students’ interest in mathematics and help practice and maintain skill levels. Materials that focused on rich problems included problems that required more in depth thinking and problem-solving on the part of the students, and helped guide students towards an understanding of mathematical concepts and/or real life relationships with mathematics. Project materials were designated as longer, more involved problems, where students would need to devise a plan to work through stages of problem
solving. The end result of a project also includes students explaining in more depth their thought processes and the meaning of their results.

Karen assembled a resource package for teacher participants, which was given to them at the start of our first meeting. We used this package to provide materials to initiate and focus our group discussions, and to help offer incentive for teachers to participate in IMTIG. The package consisted of a binder full of activities, rich problems, and projects, as well as other teaching ideas, readings, and a bibliography. Karen selected these materials from her own vast collection of resources that she has gathered during her teaching career. She also added some new ideas from books, recent workshops she had attended, and the Internet. In addition to the binder, the resource package also contained a bag of tools, including dice, cards, a pencil and eraser. Teachers brought their resource packages to every IMTIG meeting, and we chose all our activities, problems, and projects to discuss and implement from this package.

The IMTIG meetings took the following structure: Our first meeting was the all-day Math Camp, where we began with an initial questionnaire for the teacher participants, followed by discussions about the goals of the project, the expectations for the participants and the researchers, and ideas about the use of activities. Then Karen guided us in a number of activities from our resource binders. After trying them as if we were students, we then discussed the details of each activity, the mathematical concepts involved, how they could be implemented in a classroom, and what to expect from students. Just before the end of the meeting, as a group, we agreed upon which activities each teacher would try with their own classes in the next few weeks.
The following three meetings were shorter, after school meetings. During the second meeting we began by discussing teachers' implementation of the chosen activities; this discussion took approximately half the meeting time. Then following a short break, Karen guided us in a number of rich problems before we discussed the details of each problem, as we had done with activities. Again we agreed upon a few problems for participants to try in their classes before the next meeting. The third meeting was exactly the same structure as the second meeting, beginning with discussions about rich problems and ended with discussions about projects. The fourth and final meeting began with discussions about projects, and ended with a general discussion about the project and teachers completing final questionnaires for our data collection.

The design of IMTIG was different than the other learning communities reviewed in chapter two. The local setting, amount of time, and level of financial support for IMTIG was unique and therefore required that we adapt some of the ideas from other successful learning communities to attempt to meet the needs of our local context.

**Site and Setting**

The IMTIG project took place in two locations: The inquiry group meetings were held in a classroom at Harbour Elementary School, in the Sea Side School District, and the trial implementation of activities, rich problems, and projects took place in participating teacher’s classrooms in the same school district. The Sea Side School District was selected because my research partner for the data collection, Karen Jones, is a teacher at Harbour Elementary School and therefore in the Sea Side School District. Harbour Elementary School was selected for the inquiry group meetings because we had access to the school and were able to use Karen’s classroom free of charge for our meetings.
The City where the Sea Side School District is located is just south of Vancouver in British Columbia, Canada. Although it is a separate city, it feels more like a suburb of Vancouver. The Sea Side School District has a mixed population of students from a wide variety of racial and ethnic backgrounds, including a large Asian population. A reasonable number of the students in the Sea Side School District are learning English as their second language. Families come from a variety of socio-economic backgrounds, although the majority are middle class.

The classroom at Harbour Elementary School that was used for our inquiry group meetings was a large room with windows along one side looking out towards the school's playing field. Most of the classroom was set up with individual student desks, while the remaining part of the classroom had one larger, round table with chairs for group projects or activities, and a counter with a sink and cupboards for storage. There were many bright posters around the room and an abundance of student work decorating the walls. The student desks were arranged in a horseshoe shape for our inquiry group meetings to accommodate the video camera and to enable all participants to see each other and thereby participate in the group's discussions.

The initial meeting for the IMTIG teacher inquiry group was held on Saturday September 28, 2002, from 9:00 AM to 2:00 PM at Harbour Elementary School. Subsequent meetings took place on Thursday October 24, Thursday November 14, and Thursday December 12, 2002, from 4:00 to 6:30 PM, also at Harbour Elementary School. The individual teacher interview was held on Wednesday November 13, from 3:00 to 3:45 PM, following the video taping of a rich problem lesson on the same day from 11:00 AM to 12:00 noon. A follow-up celebration dinner with the inquiry group was held on Thursday
February 6, 2003, from 5:30 to approximately 7:30 PM at a nearby restaurant, to thank the teacher participants for all their efforts and to celebrate the completion of the project.

Participants

The teacher participants for the IMTIG project were selected from respondents to a letter of invitation (see appendix D) and/or the posting of a similar message of invitation on an electronic message board on the Sea Side School District teacher web site. All volunteers who met our criteria of being full-time classroom teachers of grades five, six, and/or seven in the Sea Side School District were chosen, with the exception of one teacher on call who was very keen and therefore invited to join the group as well. Some of the participants were established teachers of many years, some were relatively new teachers, and two were pre-service teachers who were completing their four month long placement at Harbour Elementary School. Consent forms from all teacher participants were obtained prior to the beginning of their participation in the study (see appendix E). In total, seven teachers volunteered to participate in the IMTIG project, and five remained committed and completed the entire project. Only one of these five participants missed one meeting, the rest attended every meeting. The two pre-service teachers, Edward and Rebecca, stopped attending IMTIG meetings at the end of their practicum and did not complete the final teacher questionnaires. Therefore their involvement in the project was not described in any detail, although occasionally they were involved with group discussions that were used in the analysis portion of this paper. The remaining five teacher participants, who completed the entire IMTIG project, are described below.

Adam was a grade six/seven teacher. He taught upper elementary for his entire, four-year teaching career. Adam’s mathematics background included undergraduate
university-level mathematics courses, up to third year, as well as mathematics education methods courses during his pre-service teacher training. Adam described his past experiences with mathematics as very positive and successful, although he recalled focusing on the memorization of standard algorithms as a student. Prior to his participation in IMTIG, Adam included problems and games with his students as part of their regular mathematics instruction, in addition to regular practice with arithmetic skills. Adam’s strong mathematics background was easily apparent during our IMTIG meetings; he often shared mathematical explanations for problems and ideas that arose during our discussions and he was quick and willing to volunteer answers to other’s mathematical questions. Adam missed only one IMTIG meeting due to another commitment; yet his keen interest in the group was apparent from his active participation in the groups’ discussions and his regular sharing of events from his classroom.

Brenda was a grade six/seven teacher part time, and acting vice-principal part-time. She taught grades three through seven and had seven years of teaching experience. Although this year, Brenda was not teaching math with her class, she was still able to test some of the IMTIG activities and problems with her class as supplemental activities. Brenda’s mathematics background included only a pre-service methods course, which she felt did not adequately prepare her to teach mathematics in the classroom. Brenda described her past experiences as a student in mathematics as a struggle, and openly admitted to her lack of confidence with the subject and with her teaching of the subject. She stated that she tended to rely on the textbook, more than she liked, to cover the curriculum in math. However, in spite of this, Brenda still felt that mathematics was important, and she joined IMTIG to try to improve her teaching and increase her confidence. As an IMTIG participant, initially Brenda was very quiet, volunteering little, but as the project progressed,
she was willing to share more of her own ideas, problems, and experiences with implementing IMTIG activities with her students.

Carol was a grade five teacher with nine years of teaching experience. Carol focused her teaching career on grades four and five, often teaching them as a split level class. Carol’s mathematics preparation for teaching included the required mathematics methods course for pre-service teachers, as well as an additional assessment elective course. Carol described her past experiences with mathematics as very positive. She always enjoyed math as a student and since becoming a teacher, Carol had taken a number of professional development workshops to improve her mathematics teaching. On her initial questionnaire, Carol stated that she made use of many of the group activities and games that she learned in previous mathematics professional development workshops; in particular, she mentioned the Kim Sutton workshops as having directly influenced her classroom teaching. Although Carol did not participate as frequently in group discussions as some of the other IMTIG participants, when she did have something to contribute, Carol had usually thought it through well before sharing it with the group. Her participation in the group was therefore quite insightful at times, prompting other participants to answer questions or further reflect on their experiences. It was for these reasons that Carol was invited to participate in the individual interview portion of the IMTIG project. I visited Carol’s class just prior to our third meeting, and videotaped one rich problem-solving lesson with her class. Following the lesson, I interviewed Carol one-on-one to gain a more in-depth understanding of how the project was influencing her classroom activities and how she viewed the advantages and disadvantages of this inquiry group model of professional development.
Deborah was a grade five/six teacher during the IMTIG project, but she previously taught grades four through seven over her eleven-year teaching career. Deborah’s preparation for mathematics teaching involved only her pre-service math methods courses, but since then, Deborah attended other professional development workshops to help improve her mathematics teaching. In particular, Deborah mentioned the Trevor Caulkins workshops as having been particularly useful to her. As a student, Deborah remembered always needing to know why, and she said that this influenced her own teaching of mathematics; she also wants her students to understand the math. Deborah’s teaching focused on both this understanding and on students’ building of basic skills. As an IMTIG participant, Deborah was very talkative and involved with the project. She initiated group discussions, asked many questions, shared materials and her students’ work, and presented problems from her classroom experiences to solicit feedback from the group. Overall, Deborah was an extremely involved participant in the IMTIG project.

Samantha was the substitute teacher, or teacher on call, whose keen interest in becoming involved in IMTIG made Karen and I decide to let her join, despite the fact that at the beginning of the project, she did not have her own classroom in which to implement IMTIG activities. Samantha was a qualified teacher for five years, and taught full-time for two of those years in a private school with grades five, six and seven before becoming a teacher on call in the Sea Side School District. Samantha substituted at all grade levels, from two through twelve. Towards the end of our project, Samantha was hired to teach mathematics in a Sea Side high school, grades eight through ten. Prior to enrolling in the teacher education program, Samantha was in commerce studying accounting at university. She switched to a double major in psychology and mathematics, and then enrolled in the middle school education program at UBC to become a mathematics teacher. Samantha’s
past experiences with mathematics were very positive; she stated that she has always liked
math and that it had always come easily to her. At the beginning of the project, Samantha
said that she made use of games, manipulatives, and demonstrations while teaching
mathematics, and she also felt that drill and skill practice were important. Although
Samantha was not always able to test the IMTIG activities and problems in a classroom, she
was still an active participant in the group. She was very quick with her problem solving
and mental mathematics, and she was always willing to share her strategies and thinking
with the rest of the group.

For the classroom implementation aspect of this study, the teacher participants used
their own classrooms to test some of the activities, problems, and projects discussed during
our four inquiry group meetings. Teachers integrated these new ideas into their regular
teaching, involving students as participants in only a coincidental way. They also collected
samples of their students’ work to further analyze and share with the inquiry group. Consent
forms from parents of all students whose work was sampled were obtained prior to the
beginning of their participation in the study (see appendix F).

One teacher participant, Carol, was invited to participate in the individual interview
portion of this project. Carol was selected from the larger group of participants deliberately
based upon her potential to offer insight into the project. This decision was made based
upon Carol’s interactions with the IMTIG group during our first Math Camp meeting, and
based upon Carol’s comments in her initial questionnaire. Carol’s comments and
contributions were less frequent than some of the other participants, but were always well
thought out. In addition, Carol’s comments indicated that she was involved in at least some
level of personal reflection about her teaching practice during the IMTIG project. A second
consent form was obtained from her prior to her participation in this portion of the study (see appendix G). Carol also consented to having the implementation of one IMTIG lesson in her classroom videotaped. The parents of the students in Carol's classroom were informed about the second part of the study and consent forms were obtained from all parents of students who were videotaped prior to their participation in this portion of the study (see appendix H).

**Data Collection Process**

The data collection devices that were used in this study included video and audio recordings, written questionnaires, photocopied samples of student work, and researcher notes. The data collection methods selected were necessary because as researchers, we were also participants in the project. To determine if IMTIG could be a successful learning community, we needed to closely observe what happened during all our meetings. We were particularly interested in the discussions that occurred between teachers, and between teachers and researchers. We felt that field notes alone would not provide enough in-depth information about what happened during each meeting. We decided to videotape all the IMTIG meetings to enable us to have a complete record of everything that was said. We chose this medium because we felt it would be easier to determine who was talking from a video than from an audio recording. However, we also decided to make audiotape backups, just in case there was a problem with one of our video recordings. This turned out to have been a good decision as the audio track on one of our videotapes did not record properly and we needed to rely on the audiotape backup.

We were also interested in individual teachers' feedback on the usefulness of the project for them and their comments and ideas about how the project could be used again in
the future. The initial teacher questionnaires (see appendix I) were designed to help the researchers get to know the participants more thoroughly and to select which teacher(s) to invite to participate in the individual interview portion of the project. The final questionnaire (see appendix J) was an opportunity for the researchers to obtain participants’ feedback on what aspects of the project were most and least useful to them, and any recommendations that participants had for the development of future inquiry groups. In addition to this, the initial and final questionnaires were compared to determine if each teacher’s thinking about mathematics and about themselves as mathematics teachers changed as a result of their participation in this project. This was determined based solely on participants’ answers to questions, including, how do you feel about mathematics as a subject, and how do you feel about teaching mathematics? These two questions were asked on both the initial and final questionnaires to allow for comparison.

An individual interview was also conducted with one participant, Carol, to gain an even more in depth perspective on how IMTIG was supporting her as she implemented new teaching practice in her classroom. I videotaped the implementation of a problem-solving lesson in Carol’s classroom. The video recording of Carol’s lesson was used to document what happened in the class when she implemented a rich problem-solving mathematics lesson using some of the ideas from the IMITG group sessions. I recorded Carol’s whole class instruction and discussions as well as individual and group work as the students were solving the problem. The video recording was used shortly after the lesson as a stimulus for the follow-up interview; to solicit Carol’s comments and feedback on how her lesson went and how she felt the inquiry group professional development model was supporting her as a teacher. This individual interview was audio taped, to enable me the freedom to operate the video playback and ask questions without having to also make field notes.
All video and audio recordings were transcribed and used to document the comments and feedback from participants as well as the interactions and discourse between the members of the group. In-depth discussions were analysed and comparisons were made between what was said throughout the different group meetings.

Questionnaires were also given to participating students in each of the teacher’s classrooms. Student questionnaires (see appendix K and L) were designed to offer feedback mostly to the teacher participants but also to the researchers on students’ ideas about mathematics and the new lessons their teachers were implementing.

Although it was intended that teacher participants would use photocopied samples of their own participating students’ work to help themselves and the whole inquiry group understand what happened in their trial lessons, this was not exactly what happened. Teacher participants did bring samples of their students’ work, and photocopies of that work were taken as evidence of what happened during trial lessons. However, the amount of discussion at the group meetings that was stimulated by samples of student work was limited; teacher participants only occasionally shared selected examples of their students’ work with the rest of the inquiry group. Therefore the usefulness of the copies of student work for the project was limited.

Teacher participants were asked to keep a project journal to record their own ideas and reflections related to their participation in the IMTIG project. It was intended that this journal would be primarily intended for each teacher’s own personal reflections, and the researchers planned to encourage participants to share interesting sections of their journals with the rest of the IMTIG group and photocopy these shared sections as evidence of what individual teachers were thinking about and reflecting on with respect to the project.
However, teacher participants found they did not have enough time in their day to write regularly in their project journals, and therefore this idea was abandoned early on in the project.

Finally, researcher notes were used wherever appropriate to immediately record any ideas that occurred to us while participating in or observing aspects of this project. These notes were usually reminders of things that needed to be done and things that needed to be followed up at later meetings. These notes tended to be for myself or for Karen to help us organize and manage the project as it proceeded, and they were not used in the data analysis section of the project.

**Data Analysis Process**

The data analysis for this IMTIG project consisted of analysing the video and audio recordings of group meetings and the individual interview. It also involved analysis of and comparison between the initial and final questionnaires completed by the teacher participants.

In the first part of the data analysis, I wrote transcriptions while watching the videotapes of the four inquiry group meetings and listening to the audiotape of the individual interview. When the quality of the videotape was unclear, the audio back-up tapes were used to determine what was said. While completing the transcriptions, I also made notes along side the data; this was the first analysis of the data and it preceded any coding attempts. These initial notes included my comments on some of the discussions and ideas presented by individuals and the group, links to some research ideas from the
literature, general comments and impressions about individual participants, and comments about topics of discussion that reoccurred frequently throughout the data.

Following the completion of the transcripts, an exhaustive list of possible themes and/or categories was made from the transcribed data, which was read numerous times. This list included teaching for understanding, improving teaching practice, student generated solutions, students’ written work, assessment, student reflections, group work, basic skills, problem solving, among others. Based on these potential themes, five were selected for another level of analysis. They were basic skills, problem solving, student thinking, group work, and general teaching issues. These themes were selected because of their frequent reoccurrence throughout the data.

Additional layers of data analysis ensued, including colour coding for each of the five identified themes. Sections of the transcripts were highlighted to identify discussions and comments that were directly relevant to each of the themes. When the colour coding was complete, I made particular note of the highlighted discussions that involved deeper, longer discussions, as opposed to limited or isolated comments. Limited or isolated comments were of the kind where a teacher may have expressed an interesting idea about one of the themes chosen for analysis, but the rest of the group did not follow the lead, and no real discussion followed the initial comment. Other, more superficial discussions, also occurred frequently during our meetings when teachers talked about other topics, not related to improving student learning or teaching for understanding. These topics included, for example, discussions about school board politics and amusing anecdotes about events in teachers’ classrooms. The deeper discussions selected for this analysis included those that provided greater insight into individual teachers’ and the whole group’s thinking about each
of the selected themes. These discussions were also usually longer in length and included comments from more than one teacher. From the selection of deeper discussions, three themes were chosen for the next level of analysis.

The final three themes were selected for deeper analysis based on their frequency, the depth of the discussions, and their importance in helping to achieve the goal of the project. The themes were:

- Comparing basic skills and rich problems.
- Questioning/wondering how to support and encourage students’ mathematical thinking and communicating.
- Using group work: when and how.

In addition to these, a fourth theme was explored to answer the initial research question from the perspective of the teacher participants:

- Valuing IMTIG from the perspective of teachers.

For this fourth theme, the responses from the final questionnaires were particularly valuable, in addition to comments made during the regular IMTIG meetings and feedback from Carol during the individual interview.

Once the four in-depth themes had been selected, the deeper discussions that were previously highlighted and noted were reread and those that could be used for the final analysis were copied into the analysis portion of this paper. In addition to the copied portions of the transcripts, I also included my analysis of the selected passages, supported by ideas from research where appropriate. The purpose of the first three themes was to demonstrate how IMTIG, a learning community, encouraged discourse among its members about issues related to teaching mathematics for understanding. The final theme was
analysed to highlight both the positive and negative comments made by teacher participants during group meetings and on questionnaires about the value of IMTIG as a professional development model. A comparison was also made between initial and final questionnaires, and different group meetings, to determine if there had been any observable change in teachers’ expressed ideas and beliefs about mathematics and/or mathematics teaching.

**Context of the Study**

This IMTIG project fits into the body of research regarding the use of teacher learning communities for professional development. Learning communities have been presented in other research as alternatives to the more traditional workshop-style professional development activities (Arbaugh, 2003; Baird & Mitchell, 1997; Borko et al., 1997; Fernandez et al., 2003; Stigler & Hiebert, 1999; Supovitz, 2002), which have been shown to be ineffective in implementing and supporting lasting change in education (Fullan, 2001; Howley & Walli, 1999). To implement reform ideas in mathematics education, most teachers will need to make major changes to their current teaching practices, which will involve a great deal of teacher learning (Cohen & Ball, 2001; Hiebert et al., 1996; Simon, 1997; Stigler & Hiebert, 1999). Teachers need to be directly involved in this change process, and teacher learning will happen most effectively if it occurs within the context of the classroom. Teachers will increasingly need collaborative, on-going support as they embark on this path towards improving student learning (Baird & Mitchell, 1997; Fullan, 2001; Howley & Walli, 1999). IMTIG offers an adaptation of this idea of a teacher learning community, which was specifically designed to support upper-elementary, non-specialist mathematics teachers in the Sea Side School District.
CHAPTER 4 – ANALYSIS

Overview

The learning community that Karen and I created, the Intermediate Mathematics Teachers’ Inquiry Group (IMTIG), was designed to support practicing intermediate teachers in their efforts to better teach mathematics for student understanding by helping teachers increase their use of activities, rich problems, and projects. We based the design of our inquiry group on six characteristics found in the pre-existing literature on learning communities. They are discussed in detail in chapter two, but are listed again below:

- Creation of a collaborative, supportive environment for teacher learning.
- Focus on improving student learning.
- Attendance at regular group meetings over a longer period of time.
- Expectation that change will occur slowly.
- Inclusion of university participants, to provide teachers with access to theory and current research, and to help encourage teacher reflection.
- Trial of suggested or developed ideas in teachers’ own classrooms, followed by sharing of results with the rest of the group.

The structure of IMTIG was specifically designed to provide a collaborative, supportive environment for teacher learning. It consisted of a one, initial full-day workshop and three follow-up after school meetings spaced throughout a four-month period from September to December 2002. Teachers were also expected to test IMTIG ideas in their classrooms in between meetings, and then discuss the outcomes of their trials with the rest of the group at the following meeting. This structure of regular meetings was used by most
of the other learning communities discussed in chapter two (Arbaugh, 2003; Baird & Mitchell, 1997; Borko et al., 1997; Fernandez et al., 2003). In addition, Borko et al. (1997) noted that combining classroom work with regular group meetings was particularly effective in supporting teacher learning. Other researchers also recommend situating teachers’ learning in the context of their classrooms as a powerful way to influence and support changes in teaching practice (Putnam & Borko, 2000). With our IMTIG group consisting of willing volunteers, and with the amount of time we all spent together at the first workshop/meeting, the participants began to feel relaxed and comfortable around each other by the second meeting, thereby creating a supportive environment. Teacher participants who were mostly quiet during our first meeting volunteered their own ideas, stories from their classrooms, and asked questions by our second meeting. The kinds of questions asked by the third and fourth meetings were sometimes difficult and indicated that the group felt comfortable enough with each other to ask more complicated questions without the fear of offending each other. A similar development of group dynamics was also noted within the PEEL project. “It seemed that being involved in common concern, over an extended period of time, in an unthreatening situation where no one was sitting in judgement had generated trust and respect for each other” (Mitchell, 1995, p. 17).

To maintain a focus on improving student learning, Karen introduced activities, rich problems, and projects from the resource package, which she designed prior to the start of our meetings. The materials selected for this resource package were chosen based upon their relevance to the goal of improving student learning via teaching mathematics for student understanding. I directed discussions by asking questions and offering ideas, to promote discourse and teacher reflection on the use of these same reform materials. Supovitz (2002) recommended that teachers need guidance, in addition to structure and support, to help them
maintain a focus on the goals of the group. He noted that most of the CPS group meetings were taken up by administrative duties and paperwork instead of focusing on improving instruction. He blames this problem on a lack of guidance offered to the teachers; they had never experienced a learning community and therefore they did not know how to achieve what was expected. With our direct involvement in the project, Karen and I provided guidance to our IMTIG group, to help them focus on the goal of improving student learning.

Regular group meetings were selected as opposed to isolated workshops to help support teachers over a period of time. Although these regular group meetings were not conducted over an extremely long period of time, this was the amount of time that was feasible for our master's-level project. Teachers were strongly encouraged to come to every meeting, and we provided snacks and resources to teachers as incentive to attend. We also recruited willing volunteers and made it clear to them at the start of the project that they would be expected to commit time outside of their regular working hours to attend meetings for the IMTIG project. Other learning communities have suggested that a large portion of the success of their professional development projects can be credited to the regular meetings and interactions among group members (Arbaugh, 2003; Borko et al., 1997; Mitchell, 1995).

We recognized from the beginning that change would be slow, and therefore we expected that significant changes would likely not occur in the period of time we had available for IMTIG (four months). Borko et al. (1997), upon completion of their own learning community project, recommended, “staff development programs be at least one year in length ... so that they [the teachers] can participate with the intensity needed to make more than superficial changes in their beliefs and practices” (p. 275). Despite the
limited time available, we expected to be able to determine if the structure of IMTIG offered potential for further growth and change by searching for smaller indicators, including deeper group discussions about teaching practice and teacher issues, small changes in individual's comments and/or practice, and statements by individual participants indicating aspects of the project that were useful to them. We have located some of all of the above, and are able to offer constructive comments about the viability of learning communities like IMTIG as professional development models intended to help teachers implement some of the current mathematics reform ideas.

In the capacity of university participants, we introduced activities, rich problems and projects to the group and discussed some relevant ideas from current research, as mentioned above. Due to the time constraints of this study, the connections to theory and current research were not as strong as we would have liked, yet, as previously mentioned, we did guide discussions and ask probing questions, where we felt they were needed, to help the group embark upon deeper discussions about teaching issues. The involvement of researchers or coaches as learning community participants has been highlighted in other, similar professional development models. Other researchers suggest that without this additional guidance, teachers are likely to be unable or unwilling to maintain a focus on deeper discussions about the group's main goals. (Arbaugh, 2003; Borko et al., 1997; Fernandez et al., 2003; Supovitz, 2002).

Finally, one of the most important aspects of teachers' participation in IMTIG was that they took a number of tested and mutually agreed upon activities or problems back to their classrooms, implemented them with their students, and then during the following meeting, discussed the results of these trials. Teachers were encouraged to bring samples of
their students' work to document the kinds of student thinking and problem solving that occurred during these trials, although teachers did not do this very often. This trial of new ideas, preceded and followed by group discussion, was likely the most powerful aspect of IMTIG for initiating deeper discussions and building teachers’ confidence in their abilities to implement reform ideas in their classrooms. The CU Assessment Project discussed earlier made use of a similar structure, “This sequence – a ‘hands on’ workshop, related classroom activities, and a follow up discussion – produced some of the biggest changes we observed in the ways teachers talked about assessment” (Borko et al., 1997, p. 267).

To determine if the learning community model we developed, IMTIG, had potential use for professional development on a wider scale, I examined four themes, three of which reoccurred frequently throughout our group discussions. These included comparing basic skills and rich problems, questioning/wondering how to support and encourage students’ mathematical thinking and communicating, and using group work: when and how. The fourth theme examined other comments made by individual participants about the value of IMTIG from the perspective of teachers. These four areas will be examined here to evaluate some or all of the following: The discourse that occurred within the group, the types of changes that occurred in individual teacher’s practice, and the aspects of the project that were most useful to teacher participants.

**Comparing Basic Skills and Rich Problems**

During introductions at our first meeting, all the teacher participants expressed progressive ideas about teaching mathematics. They all wanted their students to understand rather than memorize, and they wanted to teach beyond the textbook using rich and authentic activities, problems, and projects. The teachers appeared to be aware of how math
can best be taught; many of them expressed ideas in line with current reform ideas. When asked on their initial questionnaires (see appendix I) how math can best be taught, responses included:

"Lots of talking and thinking out loud" (Adam).

"Lots of hands-on materials" (Carol).

"Relate math to kids' experience with hands-on projects" (Deborah).

"A variety of methods [including] problem-solving and using manipulatives, to learn basic computational skills" (Brenda).

However, when we began talking in more detail about particular aspects of their teaching and about activities and rich problems which they used in their classrooms, it became evident that these teachers' practice was also driven by more traditional pressures, such as preparing students for high school, providing a solid foundation of basic skills, and fulfilling the provincial curriculum requirements (called the Integrated Resource Package or IRPs).

This particular group of teachers was in a constant state of conflict between the desire to teach for understanding and the need to build basic skills:

"I would like to feel that I can meet all the IRPs without having to rely on the textbook and that students will be ready for high school" (Brenda, initial questionnaire).

"I think when I do things that I know that the kids are loving, I think about the IRPs and wonder if it's worth it" (Deborah, November meeting).

"[There is] not enough time to do it all in one class" (Adam, final questionnaire).

"I have trouble balancing what I want/feel I need to do with the amount of time" (Deborah, final questionnaire).
Time was an issue that arose often. Teachers often felt they did not enough time to balance the more traditional demands of completing curriculum and preparing students for high school, with newer teaching ideas, such as the use of rich problems. Discussions that occurred during our meetings were often about this issue: comparing basic skills and rich problems.

Members of the group contributed their own ideas about how they would help their students build basic skills during IMTIG discussions. Discussions about the use of rich problems versus the building of basic skills, provided an opportunity for the whole group to express their individual ideas, to listen to others’ perspectives, and to share their classroom experiences with the group. The discussions which follow were considered to be deeper discussions, compared to other IMTIG conversations, because the discussion topics were related to the goals of IMTIG (to improve student learning), they illustrated teachers’ thinking about the issues being discussed, and teachers discussed more than one aspect of these topics during the IMTIG meetings.

In general, Deborah expressed the most concern about providing her students with good basic skills, more than the other members of our group. Deborah initiated many of our discussions about basic skills versus rich problems in her attempts to question and understand others’ rationale for choosing problems that to her, did not provide the kind of practice students need to develop strong basic skills.

I had a thought about this problem today ... I was doing problems that were not as rich. But I still see major value in them, because of their age level [grade five-six students] and because they need to know some of these terms ... When they are developing problem solving ability and to communicate, there is a place for these
kinds of problems, to know what is a product, what is a factor. So I think I will keep
doing these kinds of problems, obviously, and those rich problems will come in
intermittently (Deborah, November meeting).

In this quote, Deborah established her perspective on the use of basic skills versus rich
problems in her classroom. Deborah was particularly concerned about providing the skills
her students needed to be successful in high school mathematics. The decisions she made
about her teaching practice were often driven by this concern.

Later, during this same November meeting, Deborah expressed concern about
having used a particular rich problem in her classroom, the bellhop problem (see below).

*The Bellhop Problem* (also called *Where Did It Go?*)

*Three travellers rent a room for $300 and split the cost three ways. Due to noisy
neighbours, the occupants complain to the bellhop and are reimbursed $50. They decide
to keep $10 each and give the remaining $20 to the bellhop as a tip. Now, if each
traveller essentially spent $90 for the room and the bellhop received $20, this accounts
for $290 of the original $300. Where did the other $10 go? Did the bellhop take it?*

The bellhop problem was one that Karen introduced during our October meeting. The
IMTIG group first solved this problem, then discussed possible solutions to it, and finally,
discussed possible student interpretations and reactions to the problem. Karen and I
considered it to be a rich problem, rather than a routine one, because the problem can be
solved in a wide variety of different ways, it can be given to students at many different
ability levels, and there is no prescribed solution method that students might be inclined to
use to solve this problem. This problem can also provide an opportunity for group or whole-
class discussions to take place as students justify their own solutions and question each
other's thinking. Following our initial discussions about this problem at the October meeting, most of the IMTIG teachers tried using this same problem in their own classrooms before we met again in November.

Parts of the discussion that occurred during the November meeting, with respect to the bellhop problem, are given below and illustrate the discourse that occurred between the group members.

Deborah: In this one [the bellhop problem], they [Deborah’s students] were just stumped ... it just didn’t go anywhere. I did it a little differently; I explained more than I usually do, reimbursement and so on. I have a lot of ESL students. It wasn’t very much fun, for them or for me.

Brenda: When I gave it to my class, they had a blast with it. The great thing for me is that I’m not teaching them math, so I can just give it to them and they can just go with it and I don’t have to worry. It isn’t part of their math mark, but still they are getting a lot out of it. Without me saying anything they made their own money and acted it out.

Adam: We had three camps and we haven’t resolved it yet. We had camps that said they each got $3.33 of the money. ... Then we had a few that said the bellhop put it in his pocket and walked off. ... Then there were a number of students who did it two ways and came to the actual answer. They did $300, subtracted $50 right away, paid the bellhop $20, then divided the remaining $30 among the three guests.

Carol: That makes it really simple.

Deborah: It wasn’t satisfying for me ... [It] was of so little value I believe, just because of the experience ... and maybe that happens.
Carol: You [Adam] had a good experience.

Adam: Yeah, and it was just that they were so keen and they all had their different solutions.

Karen: I find when I do a rich problem, it's getting to see them [the students] in a different light, how they approach it, how they get excited about it, how somebody who can't add or subtract or do any of those things, they can think outside the box, they can have some comment [on their report card] to think of them as not just things they need to work on.

Deborah: We didn't have enough time ... we haven't had the discussion part [of the problems solving activity]. But the point we were at, they [the students] were really frustrated.

Deborah initiated this discussion about the bellhop problem because she had considered her own implementation of it to be a complete failure. Adam's class engaged in a good discussion about a number of possible solutions to the bellhop problem and had a positive experience with it. Brenda was also very pleased with the outcome of her lesson, which is significant because Brenda was the only participant who openly admitted to the group that she was "math phobic" and that she disliked teaching math. However, Deborah did not feel positive about her own experience with this problem. She continued to state that the experience was not worthwhile for her because her students had struggled so much with the problem and became very frustrated with it. Yet, towards the end of this discussion, it was interesting to note that Deborah conceded that she might need to spend extra time with her class on the actual discussion part of the problem solving process instead of simply being discouraged that many students in her class were unable to reach the correct solution.

Research by others has suggested that students who are not accustomed to independent
thinking and problem solving often struggle with initial attempts by their teachers to use this kind of teaching style. Teachers need to guide their students to solve rich problems, and expect that initial attempts will result in frustration for both the teacher and the students (Baird, 1997). Had Deborah not been exposed to the other teachers’ experiences with the same problem, she may have been more inclined to place less emphasis on using this kind of rich problem with her class in the future. Instead, the group’s discussion offered Deborah some insight into the usefulness of whole class discussions about rich problems and the multiple answers and solutions that a class could generate; this offered Deborah a possible way to help her own class overcome their frustrations and another way to implement such rich problems in future lessons. This type of teacher discourse also allowed the other participants, in particular Brenda, to feel more confident and successful about what she was doing with her class. Although Brenda credits the lack of pressure, due to the fact that she was not teaching math to her students, as the reason for her successful implementation of the problem, the positive experience likely still helped to increase Brenda’s confidence as a teacher of mathematics. And although no one else discussed problems or concerns about their own implementation of the problem, this type of open discussion might reassure any other teachers who had also struggled with it that they were not alone.

While discussing projects at our December meeting, Deborah expressed concerns about her class’ weak basic skills with fractions; this interest in fractions reoccurred a number of times throughout our meetings. Deborah strongly believed that basic fraction knowledge is something that her students must master by the end of grade six. Although in theory Deborah supported the use of projects in mathematics, she did have a lot of concern about their usefulness in improving students’ basic skills. The discussion segment below
offered a demonstration of the debate that occurred about the value of projects in teaching basic mathematics skills.

Deborah: I started to create a fraction project, but when I began working with fractions with my class ... I was in shock. These were kids that I considered not terrible, but they needed to be warmed up again. So I did something different ... I decided that there is no point in doing that [project] and then just ending up spinning their wheels ... Does anybody know anything for fractions, really good math projects with a whole lot of fraction skills?

Karen: Have you ever tried quilting? Everybody gets a square and they do their divisions ... it's also an art project.

Samantha: A mosaic art project would be really cool too ... Fraction flags, they make up a country and design a flag. Then they do some population statistics.

Deborah: I guess what I'm trying to do, when you look at fractions, decimals, percents, and all that, there's the mixed numerals, there's reducing, there's all these concepts.

Samantha: What about sports statistics?

Deborah: Yeah, if you could get enough of them. The level I'm at with the five-six, they need some basic, basic stuff.

Samantha: But you can start with the bare bones, like a basketball game has four quarters.

At this point in the discussion, Deborah was asking for ideas to help her design a fraction project, but she was not satisfied with the ideas other group members offered her. Deborah's
comment above, “if you could get enough of them”, indicated that she was thinking about activities that involve more practice, possibly repetitive such as worksheets, to help students master basic fraction skills. Deborah also felt that some of the ideas offered were too sophisticated for her students, “they need some basic, basic stuff”. Although Samantha’s last suggestion was intended to help students explore very simple fraction concepts, it was apparent in the continuation of this discussion (below) that this was not what Deborah was actually looking for in a math project.

Deborah: What do you actually end up with, as far as good, valid teaching? At the end of the day, I’m thinking, will little Johnny have gotten anything out of that project? Or will he still not know a heck of a lot about half of three quarters? I feel sometimes that projects can be so rich for kids who already have tons of basics.

Janet: In doing a project, you’re looking for a deeper explanation. When you do a worksheet, they’re repeating the same skill many times. When you do a project, they may only do that skill once, which doesn’t seem like much practice, but after doing it, they also have understood it from an applications perspective, so it has more meaning, rather than just repeating the skill. And if you can get them to write something or to draw a picture, to explain what the answer means, to see if they really understand … instead of just repeating the skill.

Deborah: I hear what you’re saying, so you have that deeper understanding.

Janet: You still have to do the skills with them. [But] there are kids who appear to be very bright, who repeat skills, but can’t tell you what they’re doing. They don’t really have a deep understanding.
Adam: [They have] strong algorithms.

Janet: So you want to get at it from both angles.

Deborah: That's good.

In this segment of the discussion, I attempted to move into a more theoretical discussion about the use of projects as one means of teaching students for understanding. Deborah’s concern that using projects for basic fraction skills was not valid teaching was useful; it opened up a discussion where ideas on both sides of this debate were presented and considered by all group members. Although Deborah was the only group member to defend the need for practice to develop basic skills, the debate was likely of value to everyone. By having an open discussion, teachers were able to listen to and discuss both sides of the argument. This argument is a common one in mathematics education; which should be taught first, basic skills to enable students to solve problems, or problem solving to allow students the opportunity to discover and understand the basic skills (Hiebert & Carpenter, 1992). Although no resolution was arrived at during our IMTIG discussion, the process of talking about the ideas on both sides of the argument was valuable, as indicated by Deborah’s final comment that she was able to see the value in teaching basic skills from both a practice and understanding perspective.

Interestingly, later on during the same December meeting, Adam shared with the group an idea for a project that he had created involving a hockey pool and that he was in the process of implementing with his class. Adam chose to begin this project just before formally teaching ratios with his class and was continuing the project simultaneously with the ratio unit. He found that when he started teaching ratios, his students already had an understanding of what they meant and how to work with them; Adam’s students were able to relate the formal ratios they were learning in class to the hockey pool project. The
following quotation offered a brief description of the project and how Adam noticed a link between the project and his formal teaching of ratios.

Each week we’re keeping track of who’s in first on points alone, but also doing a weekly thing, like this week we did improvements, like whose team had the most points just this week. Last week we did greatest number of shots on goal. We’re working on different ratios, like, what it means to have an assist to goal ratio, what does it mean to have a high or low assists to goal ratio. ... It was perfect today when we went to talk about rates, because they [the students] were already there (Adam, December meeting).

Unfortunately neither the IMTIG group nor myself, during this discussion, made note of the connection between how Adam had used his ratio project to help his students understand ratio and rates concepts prior to formally teaching them, and the earlier discussion initiated by Deborah about the usefulness of projects to teach fraction concepts and skills. This was one of the opportunities for deeper discussion and group reflection that I missed; as one of the university participants, I could have brought the group’s attention back to our previous discussion, and used Adam’s example to support the idea that using projects to teach for understanding, in this case, before teaching more procedural skills, can have a positive effect on students’ understanding of the basic skills and therefore on their learning. As Adam noticed with his own students, they were better able to grasp the theoretical information because they could connect it to previously understood knowledge gained by participating in the hockey pool and using ratios in a practical, real-life context.

Overall, this debate about the use basic skills versus richer problems was not one that we claim to have resolved during our IMTIG project meetings. However, there are
benefits to the group having had these kinds of deeper discussions with other professionals. Although no one declared that they made any major shifts in his/her thinking as a result of these discussions, this was expected due to the limited duration of the project. Yet, teacher participants did express an interest in continuing to use the types of practice we reviewed during our IMTIG meetings, beyond the end of the project. On the final teacher questionnaire (see appendix J), participants were asked if they expected to continue to use problem-based instruction in future lessons. The responses included:

"Absolutely!" (Deborah).

"If anything, my resolve to work through projects and rich activities has grown" (Adam).

"I will definitely incorporate this kind of instruction" (Brenda).

"Yes ... also by using projects ... many kids asked if we could do more projects" (Carol).

These comments indicated that even though during our meetings, some teachers expressed reservations about the use of reform materials to teach, in particular, mathematics basic skills, by the end of the project they stated that they intend to continue using this kind of teaching practice in the future. The group discussions that occurred, and teachers’ own implementation of selected activities, rich problems, and projects, supported teachers as they worked through their own ideas about the usefulness of such materials. Teachers’ sharing of their own implementation successes and failures, also provided teachers with suggestions for how they might make use of such ideas to teach for understanding in their own classrooms and to help improve student learning.
Questioning/Wondering how to Support and Encourage Students’ Mathematical Thinking and Communicating

Another reoccurring discussion throughout our IMTIG meetings was with respect to students’ thinking and communicating about mathematics and problem solving. The discussions arose from teachers’ need to be able to determine if their students are truly understanding the mathematics or not. To teach students so that they understand concepts rather than just being able to imitate skills, we also need to be able to see what students are thinking to be able to judge the success of our lessons (Borko et al., 1997). This is not something that is easy to do, especially with students and teachers who have no experience with expressing their mathematical thinking as they work. Samantha commented on this exact problem, “we were told not to think out loud, now we tell our kids to think out loud” (Samantha, September meeting). The discussions about this theme were centred around the issues of how to teach students to think and communicate their thinking, at what point are students ready to learn this, and how can teachers assess students’ thinking and communicating.

During our October meeting, Deborah expressed concern that she was not able to get the kind of deeper reflections from her students that she wanted. She was frustrated that her students were unable to communicate their thinking, and she suggested that this might be due to their young age. Deborah initiated the discussion below to share her frustrations and solicit ideas from the rest of the group. The event Deborah described took place after she had observed two of her students, one very strong and one very weak, playing a math game together during their free time. The stronger student helped the weaker student to understand how to round numbers.
Deborah: And after [the students had finished playing the math game], when we were reflecting on what we had learned, I asked [the weaker student what he had learned] and he said, no, nothing. And I thought, that’s the problem with asking kids to tell us, because I know he’s learning, but he can’t necessarily tell that he didn’t know and now he knows. To him, he just always knew.

Janet: I think you almost have to train kids to express things like that. It takes a while. I’ve done journal writing with my class and the first journal entry is like, ‘I solved this problem’, but later in the year, when they start to get into it more, they become reflective.

Deborah: And understand, yeah, their metacognitive, understanding of their own thinking.

Janet: It takes time.

Karen: I’ve had parents right in conferences ask their kids, ‘what did you do in school today?’ and they say, ‘nothing’. And I think, but at the time [during class], we were building something! And the kids were excited about it, but they can’t remember a few hours later.

Deborah: That’s why I’ve been bad about getting them to write about their activities right after. And I know that it’s gone if you don’t do it right after. So I have a few areas to improve on.

Janet: I do it sometimes while ... so as you do the math you’re supposed to write simultaneously so nothing is lost. ... I find it’s really good, but it takes training.
Deborah: I think it would be really difficult with my age level ... I cannot get them to write about the problem. ... I stopped them all, had them put everything away, quieted the room, and I said, 'now write'. But they were so buzzed. It's tricky.

Deborah was frustrated with her students' lack of ability to communicate their thinking. She suggested that their inability to communicate may have been due to their young age; Deborah taught a grade five/six split, which was younger than the other classes in our group, except for one (Carol taught grade five). Initially in the conversation, Deborah said reflective writing was something that she needed to improve on; she acknowledged that she often did not get her students to reflect because she found it unsuccessful. However, by the end of this segment of discussion, Deborah simply stated that it was too difficult to get her students to reflect, implying that she could not do this because her students were not old enough to be successful at it. Although this discussion does not point to any real shifts in Deborah's thinking, she did bring up this topic for further discussion again later, thereby indicating that she was at least thinking about it and making some effort to include student reflections and communication in her teaching.

During our November meeting, Deborah again brought up the problems she was having with her students' lack of ability to communicate their mathematical thinking, this time through demonstrating their work on paper. This conversation indicated that despite Deborah's conviction at the previous meeting that her students were too young to be able to express their thoughts, she was still trying to encourage them to explain their mathematical thinking as they solved problems; she had not yet given up on reflection and communication. The following discussion was about the horse problem (see below) that Karen introduced during our October meeting, and which teachers implemented in their
own classrooms before the November meeting. The horse problem is also a rich problem, much like the previous bellhop problem, because it can be solved in a variety of ways, and can be used with groups or with whole class discussions. In the following section of discussion, Deborah began by sharing her frustration with students’ written work in math. She was concerned that students who understood what they did in their own minds were unable to communicate their thinking on paper. Other IMTIG members, who shared their own frustrations with this same issue, echoed Deborah’s concerns.

Deborah: I’ve noticed that what children communicate in writing, I noticed it in the horse problem, we took the problem, we did it in class, we set up camps, then their homework was to go home and talk to their parents about it, come back and then set up camps again and a lot of people moved over [to a different camp]. I still had these two girls who said it was $10, but their written work said it was $20.

Carol: I had that happen too!
Deborah: The student said she made $10 and then she made $10 again. So what happened? Was she not getting that the answer was supposed to be the total? ...

Janet: For me, this is where projects are useful because students have more time to spend on them and you can emphasise that communication is equally important as the answer and how you got the answer. Then it forces the students to sit down and thoroughly explain everything.

Edward: Some people scribble for a while, then scratch it out, then they try it again, so it isn't nicely written.

Janet: But when you get to the end, you can still explain what you did.

Karen: Like, first I tried this, and that didn't work, so then I tried this. I've seen some teachers who put like a caption; they get their students to explain what they were doing at each part of their solution.

Carol: Faye Brownlie says to use the double-sided thing, put your working on one side and your thinking on the other side.

Janet: Shelia Tobias is big on doing that. Doing the math and thinking simultaneously.

Deborah: With the little guys, the younger ones, with their math folders, they are getting much better about showing their work. When you have 28 students, you just can't go around to see everybody, so you really have to rely on their written work. So what I find is that I get a kid that I know mathematically they are very aware, but the work isn't there; there is nothing there for you to grade. They look at a problem and think it is easy and so they don't go anywhere with it, they just write the answer. So you
go back and talk with them, and I find it very discouraging to try to draw what’s in their head out and get it on paper.

Brenda: Even with mine, I find that I look at their work, and they’ve done all their work, but they’ve erased it all and left only the right answer.

Deborah: I’m trying to tell them that the work is the good stuff.

A number of group members shared their frustrations about their efforts to get students to communicate in writing more clearly and effectively in math. This shared dissatisfaction also lead Karen, Carol, and I to offer some suggestions for how students might be encouraged to better communicate. All three of us offered the same recommendation, but from different sources; get students to explain what they are thinking while they are solving the problem instead of waiting until they finish the problem. One positive outcome from this group discussion, therefore, was that we all shared a common concern about our teaching practice, and as a group, we were also able to generate a potential solution to our problem.

A short time later during the same November meeting, Deborah highlighted some strong communication that a few of her students demonstrated while solving the same horse problem (see appendix B).

Deborah: I had kids come up to the board during the horse problem and they were so clear in their explanations and I was awed.

Previously, Deborah had only expressed frustration and concern that her students were not effective communicators in mathematics. However, in this quote, she appeared pleasantly surprised that some of her students could be very effective communicators. Yet, in the section of the discussion that followed, Deborah was surprised to see that other students in the class were unable to recognize the validity of a correct solution when compared to their own wrong solutions.
Deborah: [Yet] the kids on the other side [of the discussion about the right solution] were locked into what they had decided and they weren't open to changing. I know that sometimes it is hard to follow someone else’s thinking, but sometimes they [the students with the right explanations] were just amazing, those kids who were explaining, and you would expect that that might do it [change the students’ minds with wrong solutions].

Carol: It would be interesting to see as they do more [rich problems], [if they] get more flexible.

In the last part of this discussion, Carol suggested to Deborah something that I had also mentioned a few times previously with respect to these “new” ways of teaching mathematics; students need time to get used to expressing their thinking, solving rich problems, and in this case, listening to and considering the value of other possible solutions (Baird, 1997). It is interesting that it was Carol who recommended this idea to Deborah since Carol taught a straight grade five class while Deborah taught a split five/six class. Deborah had previously used the justification that her students were too young to be able to participate in some of the teaching ideas suggested during IMTIG. It was possible that with Carol suggesting this idea to Deborah, instead of me, that Deborah might have been more likely consider the possibility that her students were in fact mature enough to handle this kind of activity. Carol’s position, as a teacher of the same grade level as Deborah, may have had more influence due to her similar experience, whereas I was a high school teacher and a university researcher, and Deborah may not be able to accept my suggestions as ones that would be as relevant to her own teaching level and context.
Carol, despite the fact she taught grade five, encouraged her students to express their thinking while solving problems. I visited Carol’s classroom one day to videotape a problem-solving lesson. During the lesson, part of the time was allotted to students sharing their thinking with the class. Although some of them needed guidance from Carol to be clear for the rest of the group, she took the time to guide them and to teach them how they could improve their communication in mathematics. “When one little guy came up to the board to explain on the board, I kind of helped him out, after he explained each part” (Carol, November meeting). Carol and I watched parts of the video together following the lesson and Carol was amazed at how well some of her students were able to share their problem solving strategies with the camera and myself. “I should get him to share, I’ll get him to share it at the beginning of class tomorrow. It’s interesting” (Carol, interview). Carol was particularly interested in the opportunity to watch the video; it provided her with a chance to listen to her students’ thinking. “It was great for me, after school, to see the video. I got to hear through the video what every group was doing, you never get to do that, so that was really neat” (Carol, November meeting). This opportunity also likely helped Carol to realize how well her students were able to communicate their mathematical thinking and problem solving. Carol’s example illustrated that, despite Deborah’s claim that fifth grade students were too young; they can in fact learn how to communicate their mathematical thinking.

**Using Group Work: When and How**

The IMTIG teachers debated on a number of occasions how and when to most effectively make use of group work to teach their students. Every teacher, at some point
during our IMTIG meetings, stated that they used group work in their teaching, but following our conversations, it became apparent that some teachers used group work only to share individual solutions, while others used group work to build and share group solutions. Proponents of teaching mathematics for understanding support the use of group work to build group solutions; the discourse that comes from such interactions and the multiple solutions that often result are valuable learning tools (Hiebert et al., 1996; NCTM, 2000; Simon, 1997). As one of the research participants, I voiced this view a number of times during our group work discussions, to stimulate debate and to encourage teachers to consider alternate ways to use group work in their classrooms.

During our October meeting, a discussion about group work took place following our trial of the horse problem (see appendix A). The following discussion was an example of the kinds of discussions that occurred throughout our IMTIG meetings about group work. Karen introduced the problem to the group, and then each participant spent time alone working out a solution. Once everyone was ready, we shared our different solutions with the rest of the group. Following this, I suggested that group work could also be a powerful way for students to work together to solve problems, instead of just sharing individual solutions. The discussion below, about when and how to use group work, followed.

Janet: I think group work is great, because then what happened to you [Edward had misinterpreted the meaning of the problem] when you were working alone, wouldn’t have happened, because you would have been with a group of two or three people and you would have been discussing it. So as soon as you explained your thinking, or somebody else in the group said, I don’t understand or I see a flaw in your logic, then you’re forced
to rethink it and re-defend ... usually the group can put together a better answer than an individual.

Karen: I don’t know, I feel when I give my kids a problem to solve in a group, it depends how big the groups are too, but they often let one person do all the work. And the other [students] might be contributing verbally, but they might not be, so every once in a while I like them to all take a minute to do it by themselves.

Carol: It [working alone] takes off some of the pressure [of working in groups].

Deborah: I always do [groups of] one, two, four. ... I look around and those kids who are working [well alone] get to keep working by themselves, and those kids who are stuck, I say, to get unstuck, talk quietly to the person next to you [in groups of two]. It gives the kids who want to keep working alone the opportunity [to keep working alone]. ... Especially if you are with kids around you who are really getting the problem fast, and so you don’t get the opportunity to do it because they’re already ahead of you. ... [When the students] get to the point where they’re at [groups of] four, they’re verifying their own solutions [with other students].

During this discussion, teachers discussed the advantages and disadvantages of solving problems in a group. At this point, Karen, Carol, and Deborah all supported the use of group work, but only after students had had a chance to think about and solve the problem on their own. They were concerned that when students worked in groups, the stronger students came up with the solution more quickly than average or weaker students, who then did not get the opportunity to think about or solve the problem themselves. This was a very valid concern, and the discussion about this issue continued later in the same meeting.
Teachers' own experiences solving problems within IMTIG offered additional insight for the researchers into the issues of using group work in classrooms. During another problem that we solved as a group at the October meeting, the painting the room problem (see below), each participant individually solved the problem before the group again shared their solutions and ideas with each other. This problem generated some confusion when group members tried to understand other's solution methods. The discourse that arose lead to the following discussion segment, where teachers related their own experiences solving this problem to how students might respond to problem solving and group work in the classroom.

**The Painting the Room Problem**

*If I can paint a room in 4 hours and my friend can paint the same room in 2 hours, how long will it take us to paint the room together?*

Deborah: I find when you [Karen] are saying all that [explaining a possible solution to the problem], I find it really, really difficult to follow.

Karen: But I drew a picture.

Deborah: Yeah, but I mostly was shutting down because I couldn’t follow. That happens to kids too. They get into a conversation and they aren’t following it and aren’t getting it and not understanding, and they’ll shut down.

Samantha: I can’t think when there’s noise. So for us to discuss a problem, makes me just go crazy. I was ready to blow up after about five minutes.

Deborah: [I] think sharing too quickly is a problem. I think we have to have different ways, and we have to hear them, but until I’ve engaged, I’m not
ready to listen to somebody else’s strategy or hear other thinking until I at least have something of my own.

Both Deborah and Samantha indicated in this segment that they preferred to be independent workers, and possibly as a result of this, they tended to favour independent work with their students. This relationship has also been supported in research; teachers are more likely to teach in ways they themselves were taught and ways in which they are comfortable learning (Hiebert et al., 1996).

This same discussion continued in the October meeting, with further debate about when and how to use group work with students. In the segment below, I argued further for the usefulness of using groups to build solutions, rather than just sharing individual solutions. Deborah continued to point out that this style of group work did not work for her and does not work for all students.

Janet: I think that group work should be more than just sharing your solution. It should also be about building a group solution. So that instead of each of us working through it on our own, my first thought is this and that might trigger something for someone else.

Deborah: I think that can work sometimes but I think it doesn’t too. I’ve worked that way and I just, I’ve found that I can’t think that fast. When you [Karen] were talking I couldn’t follow you.

Janet: That’s part of why smaller groups work better, because if you don’t understand you get the group to stop and the person explains.

Karen: [When I was explaining,] I was [still] thinking. [I didn’t have a full solution yet.] I’ve just got to spew it out, try to convince myself.
Janet: Part of that is that we’ve already worked through [a large part of] the solutions in our own heads. If you’re building it [from scratch], you’re not going to have a spew. You’re going to have a bit and then that may trigger a bit for somebody else. Or it might not make any sense and then you’re forced to rethink it.

Deborah: I need time to realize that it doesn’t make sense.

Carol: But if we’d started together, it might be different.

Janet: Part of that again is practice, just like [what we talked about before with] reflective writing with kids.

Deborah: With problem solving, I think the danger is I have kids in my class who totally disengage. If it was, work it out together, I know I have kids who would take turns and all that, but others who wouldn’t do anything.

The debate in this segment was similar to the first discussion we had about group work, but in this segment, the debate elaborated about more of the details, advantages, and disadvantages of implementing each type of group work. I suggested that there was value in providing opportunity for students to build solutions collectively, and that this could best be done with smaller groups. On the other hand, Deborah pointed out that there are students who cannot and/or will not work in group settings; some students are not be able to keep up with stronger students, while others just disengage with what is going on and let the rest of their group do all the work. However, in this section, Carol began to consider my argument, and suggested that the problems Deborah encountered trying to understand Karen’s explanation of the painting the room problem might not have occurred had we solved the problem together right from the start. Carol further illustrated her willingness to try this group problem solving method later when I videotape her classroom. Carol’s classroom was
organized into tables with groups of three or four, and her students worked very well together, collectively building solutions to the group problem solving activity that I observed.

The final section of this discussion began to move away from the debate about group problem solving versus individual problem solving with sharing at the end, and moved towards how we might successfully implement group problem solving with students. By the end of this segment, the IMTIG group agreed to attempt their next problem by building a group solution as opposed to simply sharing individual solutions.

Karen: So what’s a good number of kids to be working together on something like this [group problem solving]? At this level, grades five, six, seven?

Carol: Probably just two or three.

Deborah: And I like to take a kid who’s really strong and make him work with a kid who’s really strong, rather than having one kid who always gets the answer instantly with another kid who barely understands the beginning of what the problem is meaning. I don’t think that’s helpful.

Karen: Why don’t we try the next [problem] in groups of three?

Throughout the prior discussions about group work, Deborah was consistently opposed to having students work together to generate solutions; she instead supported individual work followed by group sharing of completed solutions. However, in the above segment, Deborah began to consider how she might implement group problem solving in a classroom, and she offered some recommendations. Deborah was still concerned that students might disengage during a group problem solving activity, so she recommended grouping students together with similar ability levels to minimize the possibility that a stronger student might take over the group. At the end of this discussion, Karen suggested that we solve the next problem
together using groups right from the start, instead of taking time individually to think about the problem. The IMTIG group agreed, and we did attempt to do this, unfortunately we also ran out of time. I would have liked to have completed the next problem and then discussed the experience. The comparisons between these two different methods of group work would hopefully have resulted in further debate, and possibly lead to more recommendations from IMTIG members for when and how to use group work, and which kind of group work might be best for particular kinds of problem solving activities. Although we were unable to do this, the discussions that did take place exposed teachers to a variety of ideas and recommendations for using group work with their students. In at least one teacher’s case, following this discussion, Carol did implement the group work method of building of group solutions with her students during her videotaped lesson.

**Valuing IMTIG from the Perspective of Teachers**

The learning community concept that we adopted to create IMTIG offers potential as a professional development model to help teachers implement richer activities, problems, and projects to increase students’ understanding of mathematics. Part of the value in any professional development model is based upon the experience of the participants. The IMTIG teachers made a number of positive comments about their participation in the group, as well as some recommendations for improvements for future inquiry groups or learning communities.

Every teacher who completed the whole IMTIG project commented very positively with respect to the teacher community that developed and the discussions and experiences shared by the group members. In response to the question, ‘what aspects of your
participation in this project did you find most rewarding?’, teachers wrote the following comments on their final questionnaires (see appendix J):

“Talk times and sharing of experiences” (Adam).

“Found discussions with others to be so valuable” (Deborah).

“Talking with other teachers about teaching math” (Carol).

“Appreciated the chance to find out what other people are doing in their classes with math” (Brenda).

“Sharing and listening to everyone else” (Samantha).

Carol also added during her interview with me, “It’s nice because it’s ongoing, it’s not just a one-shot deal. You get to go and try some things and come back again, try some things and come back again. I like doing that.” In addition to valuing the group’s discussions and regular, shared experiences, all of the teachers also appreciated the resource binder that was provided by Karen and the additional resources and ideas shared by other participants.

Samantha and Brenda made special mention on their final questionnaires (see appendix J) of the power of teachers working collaboratively to help each other improve teaching practice. “If individual teachers help each other improve, we each reap the benefits” (Samantha). “I think this is such a valuable experience because as teachers we almost never get a chance to share ideas. ... It is such an amazing way to learn” (Brenda).

Carol indicated on her final questionnaire that her participation in the group helped her to think more about her own students’ learning. She particularly valued the opportunity to have one of her problem-solving lessons video taped, which gave her the chance to observe how her students were thinking about and solving a given problem. Carol wrote that the aspect of the group that she found to be most rewarding was the opportunity “to think about ways to make math a more rich experience for my kids” (Carol, final questionnaire). It was
interesting to note the language used by these teachers to describe their experiences; they referred to IMTIG as a way for teachers to “improve” and “learn” and to be focused on student learning. These comments are in line with recommendations from many researchers, who suggest that to successfully implement reform ideas in education, teachers need help to focus on and learn new ways to improve their practice with the ultimate goal of improving student learning (Baird & Mitchell, 1997; Baird & Northfield, 1995; Hiebert & Stigler, 2000; Howley & Walli, 1999; Knight, 2002; Simon, 1997). Based upon the comments and feedback from IMTIG participants, their experiences helped them to learn about and focus on improving their teaching and student learning.

In addition, Deborah also commented on the value of the role Karen and I played as university participants on her final questionnaire. “Karen and Janet’s comments and sharing were extremely insightful and helpful. Janet I found your observations always thought provoking.” Deborah appreciated the additional comments and questions we posed to the group and the encouragement and stimulation we provided for teacher reflection. Deborah also mentioned in her final questionnaire that she spent quite a bit of time during the IMTIG project reflecting on her own practice. Other learning community models have found that involving a university participant or coach, to help teachers connect their work to research and theory and engage in reflections, is an important component of the learning community’s group dynamics and further supports the learning of teachers (Arbaugh, 2003; Baird & Mitchell, 1997; Borko et al., 1997; Fernandez et al., 2003). As university participants, Karen and I accomplished this by presenting problems, ideas, questions, and outside encouragement for IMTIG participants to engage in group discussions and reflections about their teaching.
It is difficult to determine if or when change occurs in teachers’ beliefs, and whether long term, lasting changes in teaching practice will occur from such a short project. However, there does appear to have been a significant change in one participant’s attitude towards mathematics and her teaching of mathematics as determined by written feedback on the questionnaires and her participation in the group meetings. Brenda wrote on her initial questionnaire, “I wish I enjoyed teaching math more, but I don’t feel terribly confident and tend to rely more on the textbook. I am intimidated by students who know more than I do.”

During our first IMTIG meeting in September, Brenda spoke very little and mainly observed the group’s discussions. By the second meeting, however, she became a much more involved participant, sharing her own experiences from implementing IMTIG activities in her classroom. Brenda spoke for quite a few minutes during the October meeting, describing for the group what happened when she implemented some of the activities from our previous meeting with her class. From her comments, Brenda’s trial lessons were very successful, “It was great. Really, really fun” (Brenda, October meeting). Brenda also was only teaching her class half time. She was not the regular mathematics teacher, and so these IMTIG activities that she tried with her class were not graded and were not connected to lessons or a curriculum. This lack of pressure likely helped Brenda relax more while implementing the IMTIG lessons. “It was probably more fun for me because, that’s it. I don’t have to go on and do a math lesson, it doesn’t have to be part of something. It was a spontaneous kind of thing” (Brenda, October meeting). Following this first, very positive experience with IMTIG activities, Brenda became an active participant in the group. She shared more of her own classroom experiences, volunteered her own solutions to problems that we solved together, and asked questions of other group members. She even began to think more about how she could create her own math projects from activities she
was already involved in. By the end of the project, Brenda expressed much more positive
and confident ideas about mathematics and mathematics teaching. In her final questionnaire,
Brenda wrote, “I do feel better about math as a result of this [IMTIG] project. ... I think the
fact that my attitude towards math has changed is hugely rewarding.” With respect to her
teaching practice, Brenda wrote, “I am more excited about teaching math now. ... I will
definitely incorporate this kind of instruction [in the future].” Brenda’s professed
improvement in her attitude and confidence towards mathematics can be considered one of
the largest accomplishments of this project.

There were some recommendations made by the IMTIG teacher participants about
how the project could be run differently in the future. The biggest concern that participants
had was with respect to time. “It’s [the IMTIG group] quite demanding time-wise with the
busy life of teachers, so it has limited attractiveness” (Deborah, final questionnaire).
Deborah was writing about the potential of IMTIG for future professional development
models. Her feelings were echoed by Carol during her individual interview with me, “It’s so
hard to get people to commit to after school things, and we’ve got this assessment
committee and there’s all these sorts of things coming at us through the government with
these accountability contracts and performance standards”. As Carol and other researchers
suggest, there are often many other initiatives competing for teachers’ attention in every
school, therefore inviting teachers to participate in another after school project may be
expecting too much of their time and energy (Fullan, 2001; Supovitz, 2002). Other
researchers who recommend the use of any kind of learning community also warn that
adequate time and support must be provided if this type of professional development project
is to succeed (Arbaugh, 2003; Baird & Mitchell, 1997; Borko et al., 1997; Fernandez
et al., 2003; Stigler & Hiebert, 1999).
Other recommendations from the teacher participants about how the project could be improved dealt more with the specific details of IMTIG. Adam wished he had more time to implement new lessons with his class before we held our next meetings. Brenda suggested that we discuss more theory about problem solving to help teachers better understand how to implement this type of instruction in their classes. Deborah recommended that, in addition to the whole group meetings, we should organize partners who teach similar classes to work more closely together, to collaboratively design new lessons, to observe each other's classes, and to offer each other more feedback on how to improve their teaching practice. Overall, the comments and recommendations made by IMTIG participants were either positive or constructive in nature, indicating that teachers were generally pleased with their involvement and the outcomes of IMTIG.

**Summary**

The group discourse that occurred during IMTIG meetings suggested that teachers were engaging in deeper thinking and reflection about their teaching practice. Discussions and debates that occurred between group members provided opportunities for teachers to work through new reform ideas and understand how new practice might fit into or alter their existing ideas about teaching and learning. This sense of community that developed during IMTIG is considered by Fullan (2001) to be essential if improvements to teachers' practice are to happen.

There is no getting around the primacy of personal contact. Teachers need to have one-to-one and group opportunities to receive and give help and more simply to converse about the meaning of change. Under these conditions teachers learn how to use an innovation as well as to judge its desirability on more information-based
grounds; they are in a better position to know whether they should accept, modify, or reject the change. ... Purposeful interaction is essential for continuous improvement (Fullan, 2001, p. 124).

While comparing how best to incorporate both basic skills and richer problems, teachers shared their ideas and classroom experiences with the rest of the group. These conversations generated recommendations for others, and were venues for teachers to share their successes and frustrations with the rest of the group. By the end of the project, all teachers involved expressed a desire to continue to use IMTIG type teaching practice in their classrooms.

As teachers worked through how best to support and encourage student thinking and communicating in mathematics, many group members shared similar frustrations about students' limited abilities to reflect and communicate. Again, the discussions that took place enabled teachers to consider different teaching practices that might support students' mathematical thinking. These discussions also facilitated the sharing of teachers' stories and experiences, such that teachers of similar grade levels were able to discuss what worked and what did not work in their classrooms. Although most teachers found that trying to get clear, coherent thinking and writing out of their students was difficult, at least for the duration of this project, they continued in their efforts to accomplish this.

Discussions about when and how to use group work in mathematics teaching revolved around the use of group work to share individual solutions versus the use of group work to build group solutions. The debate that took place explored issues that arose in IMTIG teachers’ classrooms as well as those that arose while IMTIG participants solved problems themselves. By the end of the debate, recommendations were made for how to
implement the building of group solutions while considering the concerns that had initially lead to teachers' use of more individual work. Following these discussions, at least one participant, Carol, implemented the group problem solving ideas in her own classroom.

Comments and recommendations made by participants about the usefulness and value of IMTIG indicated that they had found the experience to be relevant and useful to their professional practice. Teachers were particularly positive about the opportunity to meet and talk with other teachers during the regular group meetings. The sense of community that developed provided the foundation for all the discussions and debates that occurred. In addition, one of the participants, Brenda, noted an obvious shift in her attitude and confidence towards mathematics and mathematics teaching.
CHAPTER 5 – CONCLUSIONS

Results and Conclusions

This IMTIG project adapted and implemented a learning community professional development model to support teachers as they worked towards improving their practice to teach mathematics for greater student understanding. The implementation of IMTIG indicated that many of the project’s features can support teachers in their attempts to improve student learning. Although change in teaching practice is something that happens over a longer period of time (Fullan, 2001; Stigler & Hiebert, 1999), and the duration of IMTIG was limited to four months, the results of IMTIG confirm that such an inquiry group model can be used to support improvements in teaching. The discourse that developed with respect to teaching basic skills versus richer problems, supporting students’ mathematical thinking and communicating, and using group work, in addition to the comments and recommendations made by participants about the usefulness of IMTIG, suggest that an IMTIG-style professional development model offers potential to support teachers as they work to implement change in mathematics education.

What is the substance of teachers’ discussions and what issues are important to teachers while they participate in a learning community such as IMTIG?

Throughout the IMTIG project, teachers engaged in many group discussions about a wide variety of teaching topics. In particular, Karen and I regularly presented the group with activities, rich problems, and project ideas related to current mathematics reform ideas.
Participants engaged in and discussed these ideas, working through problems themselves, including how to implement them, when to use them, and what to expect with their students. Next, teachers tried out some or all of the discussed activities with their students. Then, during the following meeting, these same activities, problems and projects were discussed again, after teachers had experienced them in their classrooms; they discussed how the lessons had gone, what worked, what did not work, and how they might implement similar activities in the future. These interactions with other teachers and with the IMTIG resource package, combined with classroom experiences, were valuable in helping teachers develop a better understanding of the teaching practices they were trying to implement.

The group discussions that reoccurred most frequently throughout IMTIG meetings dealt with the following issues: comparing the teaching of basic skills versus rich problems, questioning/wondering how to support and encouraging students’ mathematical thinking and communicating, and using group work: when and how. The substance of all these discussions or debates included participants sharing their personal ideas and experiences with respect to these issues, sharing their successes and frustrations with the use of related IMTIG teaching practice, and offering or generating recommendations for how they might improve their teaching practice.

The discourse that took place provided opportunities for teachers to challenge and support ideas and to listen to others’ positions about IMTIG teaching ideas. For example, while discussing ideas about how to encourage students to better communicate their mathematical thinking, I raised the issue that students who have no previous experience communicating their thinking need practice and time to begin to develop these skills. Although Deborah acknowledged my position on this issue, she suggested that her students
were too young to be able to accomplish this. However, when Carol offered the same suggestion to Deborah, it held more weight; Carol and Deborah both teach the same grade level and therefore are able to relate to each other’s experiences more easily. This varied debate with more than one participant’s perspective, was of greater influence than if I had been the only one to speak as a university expert on the same issue.

While sharing their successes and failures, teachers were exposed to ways that other teachers had successfully (or not) implemented the same IMTIG lessons and were able to benefit from the experiences of the other group members. For example, although Deborah encountered difficulties implementing the bellhop problem (see appendix A), other teachers had implemented this same lesson more successfully and were able to offer their own experiences as examples to Deborah for how she might alter her implementation of group problem solving in the future. Deborah was also exposed to the idea that, even though her first attempt had been a frustrating one, she might still find a way to use such rich problems with her class successfully in the future.

Following their discussions, the IMTIG group often generated recommendations for how they might implement IMTIG teaching practice in their classrooms. For example, after debating the issues surrounding the use of group work for solving rich problems, the group devised a compromise that incorporated the concerns of the teachers who had previously only used individual problem solving. These teachers expressed concern that weaker or less motivated students would not participate equally in a group problem solving activity. Therefore, the recommendation that arose from this discussion suggested using smaller groups of two to three students with like-ability grouping, so that it would be less likely that one student would solve the problem more quickly than the other group members.
Teacher's discussions and interactions with each other during group meetings, and their explorations of the IMTIG resources both during group meetings and in their classrooms, contributed to teachers' development of better understandings of the IMTIG teaching practices. These results are in line with previous research results by Baird and Mitchell (1997) and Borko et. al (1997), suggesting that teacher learning needs to happen both in the classroom and in regular group meetings. The joint structure employed during IMTIG enabled teachers to discuss more theoretical ideas during meetings, and also to share similar, classroom-based experiences. Where IMTIG was different from the previous research was that participating teachers all implemented the same, agreed upon activities, thereby giving them a common starting point for discussions during following meetings.

What value do teachers give IMTIG for enhancing their professional growth?

All IMTIG participants commented on the value of the regular group meetings, which enabled the group's sense of community to develop. Within these group meetings, teachers appreciated the opportunity to work collaboratively, to discuss and debate teaching issues, to share common experiences, and to reflect on their teaching practice. On their final questionnaires, all participants commented that they would continue to make use of the IMTIG teaching ideas in the future, indicating that IMTIG had enhanced their professional growth. Arbaugh (2003) and Baird and Mitchell (1997) noted this same result; they concluded that the sense of community that developed during their learning community projects was one of the major reasons for each project's success.

One participant, Brenda, did explicitly state that her attitude towards mathematics and her confidence as a teacher of mathematics had improved as a direct result of her
participation in IMTIG. It is likely that the supportive community atmosphere helped
Brenda to feel more comfortable sharing her ideas, questions, and problems with the rest of
the group; during our first meeting she spoke very rarely, but by the second meeting, Brenda
was an active participant in the group. It is interesting to note that while Brenda was an
IMTIG participant, she was not responsible for regular mathematics instruction and
mentioned on a couple of occasions how this lack of pressure had made it so much easier
for her to try teaching mathematics using new methods.

Other research has noted this same result. During the University of Colorado
Assessment Project, Borko et al. (1997) arranged with the local school district to have all
standardized testing suspended for the duration of their project. They did this to free
teachers from the pressure of preparing their students to perform well on external tests, so
they would feel comfortable trying new teaching practice in their classrooms. Many of the
discussions at IMTIG meetings revolved around how teachers could implement activities,
problems, and projects, while still meeting the expectations of curriculum, parents, and high
schools. Perhaps if the pressure that was removed for Brenda due to her unique
circumstance could have also been removed for all other participants as well, there would
have been greater shifts in teachers’ ideas and beliefs about mathematics and confidence in
their mathematics teaching.

How does IMTIG support teachers’ efforts to enhance their
practice?

The most common comment from the IMTIG teachers, upon completion of the
project, was that they appreciated the on-going opportunity to work collaboratively with
other teachers, to share ideas, ask questions, and discuss teaching issues. The group quickly
developed an atmosphere of community and support; participants who were quiet during the first meeting were much more open and willing to share their experiences, ideas, and solutions to problems by the second meeting. The regular nature of the group meetings contributed to the development of the secure, supportive environment, which helped to facilitate the group discourse that took place. As previously mentioned, other researchers have noted this same result, that regular, group meetings are essential to the development of a learning community where participants have a sense of commitment and support for each other. It is within this kind of group that improvements in teaching practice are more likely to occur (Arbaugh, 2003; Baird & Mitchell, 1997; Borko et al., 1997).

Karen and I also played an important role in the development of the IMTIG group dynamics by guiding and directing discussions to help maintain a focus on improving teaching practice. Karen presented the teaching materials that directed the group discussions, and I asked questions and made comments during these discussions designed to encourage deeper discourse and reflections. These two roles were necessary to help the group maintain its focus on improving teaching practice and hence student learning. However, in spite of our efforts, there were times when group discussions wandered into what is commonly called ‘teacher talk’. Political concerns within the local school board, classroom management problems, workload issues, and other general conversation often came up during the IMTIG group meetings. This example further highlights the importance of the role that Karen and I played as active university participants in helping to guide conversations towards the goal of each meeting. It is expected that without this structure and guidance, the IMTIG group would have spent even more time conversing about teacher issues not directly related to teaching mathematics for student understanding. Supovitz (2002) noted in the Toyota Team Based Schooling project that groups of teachers who were
directed to create learning communities, without the guidance of external participants, spent the majority of their meeting times focused on the same kind of 'teacher talk' that occurred during some of the IMTIG meeting time. Other groups who did include university participants or coaches as participants in their learning communities, concluded that these external people contributed to the group by helping focus and direct teachers’ discussions around relevant issues (Arbaugh, 2003; Baird & Mitchell, 1997; Borko et al., 1997; Fernandez et al., 2003).

**Recommendations for Future Inquiry Groups**

**Length of Project and Time Expectations**

The largest problem encountered with the IMTIG project was the limited time that was available for duration of the project. As previously mentioned, other researchers suggest that for improvements to be observable from any learning community structure, a longer period of time is needed for teachers to be able to interact with and learn about reform ideas (Borko et al., 1997; Mitchell, 1995; Stigler & Hiebert, 1999). The time limitation with IMTIG was due to the nature of our master’s research work; for this project, we were not able to continue our research beyond four months. It is likely that this was the most central factor contributing to the project’s limited effect on participants’ ideas and beliefs about mathematics and mathematics teaching.

In addition, the project also could have benefited from release time for teachers to meet during their regular work hours. All IMTIG participants were willing volunteers, and they knew in advance that this project would require them to commit to one full Saturday and three evenings for group meetings, in addition to time in their classrooms. We were
very fortunate to find such dedicated and active participants. However, if this group was to expand to include other teachers, or if it was to attempt to become part of a school or districts’ regular professional development program, then teachers could not be expected to make such a large commitment of their own time to a learning community project. When asked on their final questionnaires if other similar inquiry groups would be possible in their own schools, Carol replied, “I think it would be difficult to get a group together in my school.” Elaborating during her interview, Carol suggested that the teachers in her school were just too busy with other committees, meetings, and regular expectations of teaching. When asked if she would consider participating again, Deborah replied, “Yes, except that it’s quite demanding time-wise with the busy life of teachers.” Other successful learning communities have secured wider support from school administrations and/or school districts, to enable teachers to meet during their school day, to schedule common planning times for teachers, to take time during their days to reflect and plan new lessons, and/or to offer financial incentives for teachers to attend meetings that do occur outside of regular work hours (Arbaugh, 2003; Baird & Mitchell, 1997; Borko et al., 1997; Supovitz, 2002). This kind of external support would likely be necessary if an IMTIG type project was ever to expand beyond a limited number of very committed, willing volunteers.

### Resource Package

The use of the IMTIG resource package was another concern for this study. One of the original intentions of this project was that the group would collaboratively produce a resource package to be shared with other teachers in the district and the province. We intended that this package would include relevant activities, problems and projects, as well as feedback from teachers with respect to implementation ideas. The purpose of this shared
resource package was to contribute to the wider knowledge base of teachers in order to help improve teaching practice over time. At the first meeting, each participant was presented with his or her own copy of the resource package. Therefore it is likely that with the abundance of resources already assembled, participants did not feel the necessity to contribute much to the package. By the end of the project, only a few group members had added anything to the IMTIG resource binder. In contrast, the PEEL project opted to provide new materials and information to its group gradually, so as not to overwhelm their teachers, and they found this approach to be very successful (Mitchell, 1997). This gradual structure would likely have better supported this desired outcome of IMTIG, to share a jointly produced resource package with other teachers. The recommendation therefore is that resources be introduced to the group only as needed, instead of all at once, and that teacher participants be encouraged to contribute to the development of a group resource package.

**Theory and Research**

As university participants, Karen and I attempted to provide resources and guidance to assist the IMTIG group in their process of understanding and implementing reform ideas in their mathematics teaching. Although we did include ideas from theory and research during our group discussions, it would have also been useful for the group to have been expected to complete readings about the theory and research that supports and justifies the reform efforts we were working with.

Arbaugh (2003) included a time for reading during part of each of their group meetings. She concluded that the readings presented to participants of the Teacher Study Group helped the teachers make connections between theory and practice; these connections
helped teachers to understand the reasons for the reform ideas. However, the Teacher Study Group also had access to extensive funding, and therefore was able to make time to allow teachers to read during their group meetings; teachers were paid to attend meetings outside of school time, and meetings during school time were conducted with paid release time. Although this structure would have likely also worked for IMTIG, we did not have the same access to funding and release time to enable us to use the same structure. At the start of the Teacher Study Group project, Arbaugh (2003) originally assigned readings as homework, but realized quickly that the participants did not have sufficient time to complete the readings before the following meeting. Therefore, to overcome this problem, she included reading time during each meeting. The IMTIG resource package did contain some relevant readings from research and theory for our participants to read, but IMTIG teachers also found that they did not have enough time to complete additional readings. Ideally, with a future inquiry group or learning community, a structure that included time for teachers to complete readings, linking theory and practice, would help to support teachers as they worked to understand the rationale behind the reform ideas being presented.

Research/Facilitator Reflections

My involvement in the IMTIG project has been a journey of continuous learning for me. This was my first experience with designing and implementing a research project, and I am particularly grateful to have been able to work with both Cynthia and Karen. Cynthia encouraged Karen and I to conduct a joint research project, and together, we spent a considerable amount of time discussing issues and sharing ideas related to both the design and on-going implementation of the IMTIG project. These discussions proved very useful in helping me work through both my own ideas and the research related to IMTIG. Without
these interactions, my journey would have been a much more isolated one. I would recommend this joint research structure to other magistral students who are embarking on their own research project for the first time.

This was also my first time in the role of facilitator of a teacher group. During our IMTIG meetings, I often found it difficult to focus the group’s conversations in the direction of our goals. Teachers, and likely people in general, have a tendency to talk about the issues that are most immediate to their daily lives. For IMTIG teachers, this included discussions about local school board politics, classroom management issues, meeting deadlines for paperwork, and so on. The IMTIG participants were very dedicated, willing volunteers, so I expect that this focus might be even more difficult for other, less committed groups to achieve. I believe that the role I played was a necessary one and that it greatly contributed to the achievements of this group. However, in hindsight, I would have taken a slightly more aggressive role as facilitator, asking more probing questions and recommending readings supporting the theory and research ideas that I presented during group discussions. I believe that the IMTIG teachers did make progress in the direction of improving their teaching practice, but that this progress could have been greater if they had spent more time reflecting on and interacting with the ideas and research supporting the use of the IMTIG teaching practice.

As a researcher, I often found that I noticed important connections after the opportunity to discuss them with the group had already passed. I expect that with further experience in qualitative research that that I would be able to improve my observational skills. I also found the analysis of the transcribed data to be a difficult, lengthy process. It likely would have helped if I had taken an additional course on case study qualitative
research prior to the beginning of my analysis. However, as this was my first experience with research, I had not yet finalized my ideas about my research prior to the completion of my coursework. I would recommend to future students who are embarking on their own research for the first time that they take an additional course in the relevant research methods prior to the design and implementation of their study.

Overall, I found the process of designing, implementing and writing about our own project to be a very rewarding one. I particularly enjoyed the research aspect of this project and would like to be involved in other research projects in my future teaching career.

**Summary**

There is much potential in the idea of learning communities as a means to help support teachers in their efforts to improve their classroom teaching, and hence student learning. IMTIG set out to establish such a model for future mathematics teacher learning communities and it worked. Teaching is not static but dynamic; teaching approaches must continually change to reflect changes in society, yet as previously mentioned, teaching is embedded within our culture. Teachers tend to teach in the ways in which they were taught; to break this cycle, teachers must experience new ideas in a collective, supportive environment.

Results of this study show that a teacher inquiry group can support group discourse, providing teachers with a venue to collectively interact with mathematics reform ideas. Through an analysis of the types of discourse that occurred during IMTIG, it was apparent that participants’ ideas and beliefs evolved through their interactions with the rest of the group. The discussions that took place during meetings were successful in part due to the
sense of community that developed among the participants. In addition, the university participants also contributed to the group discourse as they presented ideas and asked questions, to help the group maintain a focus on its goal of improving teaching practice.

The teacher learning that took place occurred not only during these group meetings, but also in the context of teachers’ classrooms as they worked to implement new ideas with their students. The trial of reform ideas in conjunction with regular group meetings was useful for teachers to spend time discussing new ideas, as well as discovering how they would work in practice with their students. This combination provided opportunities for teachers to discuss multiple aspects of the ideas raised during group meetings.

The regular group meetings were essential for the development of the teacher community. The group needed to meet regularly over a period of time, to get to know each other and feel comfortable sharing ideas and asking questions. They also needed a longer period of time to interact with and absorb new ideas. As described in the analysis, a number of discussion topics reoccurred during more than one meeting as teachers worked to understand the rationale and implementation for new teaching practice.

Based on the outcomes of the IMTIG project I recommend that the following features be present in the future design of an inquiry group or learning community:

• The project must continue for a substantial length of time to allow for a supportive learning community to develop, and to enable teacher change enough time to occur.

• Support is necessary from the school and district levels, to provide teachers with time and resources so they can devote their energies to the project.
University or other external participants are needed to help the group maintain a focus on the goals of the group. They need to provide access to reform materials, theory, and research, and they need to ask probing questions to encourage deeper discourse and teacher reflection.

Teacher learning needs to take place in the classroom as well as during group meetings. Teachers need to try new teaching practice in the context where it will be employed, and discuss the results of their efforts with a learning community following these trials.

Where possible, teachers need to be released from external pressures, to enable them the freedom to test new ideas in their classrooms without fear of repercussions for failed attempts.

This IMTIG study has demonstrated that inquiry groups or learning communities have a great potential to support teachers in their efforts to change. However, they are still a relatively new professional development idea and therefore are limited in numbers. Future research could explore possible ways to more broadly implement the learning community professional development structure. Currently, research projects involve, for the most part, exceptional volunteers, teachers willing to commit large amounts of extra time to special projects. To implement learning communities on a broader scale, ways must be found to involve more teachers, including those who have less time available to devote to group meetings or improving individual practice. A culture of collaboration and improvements to teaching practice must develop, like in Japan, where teachers participate in lesson study and it is a cultural expectation that teachers will work continuously towards improving their teaching practice, slowly over time (Stigler & Hiebert, 1999). This attitude towards teacher learning does not yet exist in North America. To widely implement learning communities,
current professional development funding must be restructured and ways must be found to support and encourage all teachers to work towards continuously improving their practice.
REFERENCES


APPENDIX

A – The Bellhop Problem

(Also called: Where did it go?)

Three travellers rent a room for $300 and split the cost three ways. Due to noisy neighbours, the occupants complain to the bellhop and are reimbursed $50. They decide to keep $10 each and give the remaining $20 to the bellhop as a tip. Now, if each traveller essentially spent $90 for the room and the bellhop received $20, this accounts for $290 of the original $300. Where did the other $10 go? Did the bellhop take it?

B – The Horse Problem


A man bought a horse for $50.
He sold it for $60.
Then he bought the horse for $70.
He sold it again for $80.
What is the financial outcome of these transactions?
(Ignore the cost of the feed of the horse, cost of boarding, etc.)

C – The Painting the Room Problem

If I can paint a room in 4 hours and my friend can paint the same room in 2 hours, how long will it take us to paint the room together?
TO PARTICIPATE IN THE INTERMEDIATE MATH TEACHERS' INQUIRY GROUP (IMTIG), PLEASE COMPLETE AND RETURN THIS CONSENT FORM

☐ I CONSENT to my participation in the above stated project and agree to the videotaping of all group sessions, the sharing selected excerpts from my project reflection journal, and the saving of all email correspondences related to the project. I understand that with my consent to participate in the project I will make an effort to attend the one-day workshop, attend all inquiry group meetings and include some of the project ideas and activities in my teaching. I have read the attached project information and understand the nature of my participation in this project. With my consent I acknowledge receiving a copy of all 3 pages of this consent form.

Name (please print): ____________________________________________

School name and address: _______________________________________

Email: __________________________ Work Phone: _______________________

Signature: ______________________ Date: _____________________________

☐ Please check this box if you are interested in receiving a copy of the final reports based on the findings of this project.

Copies will be distributed either by email or regular mail. Please indicate how you would like to receive your copy of the final reports.

☐ I would like to receive an electronic copy of the final reports by email.

☐ I would like to receive a paper copy of the final reports by regular mail.
INTERMEDIATE MATH TEACHERS’ INQUIRY GROUP
PLEASE RETURN THIS CONSENT FORM

Please check the box indicating your decision:

☐ I CONSENT to my child’s participation in the above stated project and agree to the photocopying of my child’s work and to allow my child to complete two questionnaires. I have read the attached project information and understand the nature of my participation in this project. With my consent I acknowledge receiving a copy of all 3 pages of this consent form.

☐ I DO NOT CONSENT to my child’s participation in the above stated project as described in the attached form. I acknowledge receiving a copy of all 3 pages of this consent form.

Child’s Name (please print): ____________________________

Parent/Guardian Name (please print): ____________________________

Signature: ____________________________ Date: ____________________________

☐ Please check this box if you are interested in receiving a copy of the final reports based on the findings of this project.

Copies will be distributed either by email or regular mail. Please indicate how you would like to receive your copy of the final reports and include the relevant contact information.

☐ I would like to receive an electronic copy of the final reports by email.

Email Address (optional): ____________________________

☐ I would like to receive a paper copy of the final reports by regular mail.

Postal Address (optional): ____________________________

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TO PARTICIPATE IN PART 2 OF THE INTERMEDIATE MATH TEACHERS' INQUIRY GROUP (IMTIG), PLEASE RETURN THIS CONSENT FORM

☐ I CONSENT to my participation in the above stated project and agree to the videotaping of my classroom teaching and the video taping of my interviews. I have read the attached project information and understand the nature of my participation in this project. With my consent I acknowledge receiving a copy of all 3 pages of this consent form.

Name (please print): _____________________________________________

School name and address: ___________________________________________

Email: _______________________________ Work Phone: __________________

Signature: __________________________ Date: _______________________

If you have not done so already, please complete the following:

☐ Please check this box if you are interested in receiving a copy of the final reports based on the findings of this project.

Copies will be distributed either by email or regular mail. Please indicate how you would like to receive your copy of the final reports.

☐ I would like to receive an electronic copy of the final reports by email.

☐ I would like to receive a paper copy of the final reports by regular mail.
INTERMEDIATE MATH TEACHERS' INQUIRY GROUP, PART 2

PLEASE RETURN THIS CONSENT FORM

Please check the box indicating your decision:

☐ I CONSENT to my child’s participation in the above stated project and agree to allow my child to be in the range of the video camera while recording two math lessons taught by my child’s teacher. I have read the attached project information and understand the nature of my participation in this project. With my consent I acknowledge receiving a copy of all 3 pages of this consent form.

☐ I DO NOT CONSENT to my child’s participation in the above stated project and do not agree to allow my child to be in the range of a video camera as described in the attached form. I acknowledge receiving a copy of all 3 pages of this consent form.

Child’s Name (please print): ____________________________________________________________________________

Parent/Guardian Name (please print): __________________________________________________________________________

Signature: ___________________________ Date: ___________________________

☐ If you have not already done so, please check this box if you are interested in receiving a copy of the final reports based on the findings of this project.

Copies will be distributed either by email or regular mail. Please indicate how you would like to receive your copy of the final report and include the relevant contact information.

☐ I would like to receive an electronic copy of the final reports by email.

Email Address (optional): __________________________________________________________________________

☐ I would like to receive a paper copy of the final reports by regular mail.

Postal Address (optional): __________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________
Intermediate Math Teachers’ Inquiry Group – Initial Questionnaire

Please print your name and complete the following questions.

Participant’s Name: ________________________________

Questions:

1. How long have you been teaching?

2. For how many of those years have you been teaching mathematics?

3. What grades of mathematics have you taught?

4. What kind of formal training have you had regarding teaching mathematics? Do you feel this training prepared you adequately for your needs as a mathematics teacher?

5. Please describe your own past experiences as a mathematics student (elementary school, high school, university).

6. How do you feel about mathematics as a subject? Do you feel it is important, not important, or are you indifferent? Please explain the reasons for your answer.
7. How do you feel about teaching mathematics? Do you enjoy teaching it, dislike teaching it, or are you indifferent to teaching it? Please explain your answer.

8. How do your math lessons fit into your weekly teaching timetable? Do you teach math everyday, every other day, for a single period, a double period, in the morning, in the afternoon?

9. What materials and/or textbooks do you currently use to teach mathematics? Please be specific when giving textbook titles.

10. Please describe what teaching methods you use when teaching mathematics.

11. Do you integrate or have you ever integrated math into other subject areas, for example, into science, social studies, etc? If yes, please explain what subject and how.
12. Have you had any comments or suggestions from parents regarding the mathematics curriculum and/or lessons? If yes, what were they?

13. In your opinion, what is the most effective way to teach mathematics? Please explain.

14. In your opinion, what are the qualities of a good mathematics student? Please explain.

15. Please describe your past experiences (if any) with problem-based mathematics teaching or learning.

16. What would you like to get out of your participation in this mathematics inquiry group? Please include any suggestions or comments. You may continue on an additional paper if necessary.

Thank you for your responses. Please return this questionnaire to one of the project investigators.
Intermediate Math Teachers' Inquiry Group – Final Questionnaire

Please print your name and complete the following questions:

Participant's Name: ____________________________

Questions:

1. How do you feel about teaching mathematics? Do you think your answer has changed from the beginning of this project? Please explain your answer.

2. In your opinion, what is the most effective way to teach mathematics? Please explain.

3. In your opinion, what are the qualities of a good mathematics student? Please explain.
4. What aspects of your participation in this project did you find most rewarding? Please explain.

5. What aspects of your participation in this project would you like to have seen done differently? Please explain.

6. Do you expect that you will continue to use problem-based instruction in your mathematics classes in the future? Please explain.

Thank you very much for the time and effort you devoted to this project. Your participation and feedback was invaluable and very much appreciated. Please return this questionnaire to one of the project investigators.
Student – Initial Questionnaire

Do not write your name anywhere on this questionnaire.

Please answer the following questions:

1. How old are you?

2. What grade are you in?

3. Are you male or female?

4. What are your two most favourite subjects? Why do you like these subjects?

5. How do you feel about learning math? Do you like it, dislike like it, or neither? Please explain your answer.

6. Describe your idea of the perfect math lesson.
7. What makes a good math teacher? Please explain your answer.

8. What kinds of people are good at math? Please explain your answer.

9. What kinds of things do you think make a good math student? Please explain your answer.

10. Do you think math is an important subject? Why or why not? Please explain your answer.

Thank you very much for answering these questions. Please return this paper to your teacher.
Student – Final Questionnaire

Do not write your name anywhere on this questionnaire.

Please answer the following questions:

1. How old are you?

2. What grade are you in?

3. Are you male or female?

4. What are your two most favourite subjects? Why do you like these subjects?

5. How do you feel about learning math? Do you like it, dislike like it, or neither? Do you think your answer has changed since the beginning of the year? Please explain your answer.

6. Describe your idea of the perfect math lesson.
7. What makes a good math teacher? Please explain your answer.

8. What kinds of people are good at math? Please explain your answer.

9. What kinds of things do you think make a good math student? Please explain your answer.

10. Do you think math is an important subject? Why or why not? Please explain your answer.
11. What did you like about the new kinds of lessons your teacher has been trying in your class? Please explain your answer.

12. What did you dislike about the new kinds of lessons your teacher has been trying in your class? Please explain your answer.

13. Do you think you learned more or less math in the new lessons? Please explain your answer.

14. Would you like to have more of these kinds of lessons in your math classes? Yes or no? Please explain your answer.

Thank you very much for answering these questions. Please return this paper to your teacher.
Project Summary Report

Intermediate Math Teachers’ Inquiry Group

The intermediate math teachers’ inquiry group, or IMTIG project, was conducted from September 2002 to February 2003 with seven intermediate teachers of grades five, six, and/or seven in the Sea Side School District. If you are receiving a copy of this report, you or your child was a participant in the project, or you requested to receive information about the project when it was completed. This report is designed to provide you with a summary of what happened during the project and what conclusions were reached from the corresponding study.

The purpose of IMTIG was to find ways to assist intermediate mathematics teachers as they worked towards improving their teaching practice. There has been much research done in mathematics education that suggests students learn and remember new concepts better if they are given the chance to actively participate in their own learning. IMTIG teachers were given access to math activities, problems, and projects, designed to help students engage in their learning of new math ideas.

The participating IMTIG teachers met as a group outside of their regular school hours four times from September to December 2002 to discuss ideas related to their teaching. During these meetings, teachers tried new resources with each other and discussed possible ways they might make use of these resources with their own students. Teachers then returned to their classrooms and implemented some of the IMTIG teaching ideas with their classes. Finally, during the following group meetings, teachers discussed the results of their efforts with other teachers in the IMTIG group. Often at this time, teachers would suggest alterations or improvements to the IMTIG resources and they would help each other understand how and why aspects of their own classroom experiences were successful or not as successful as desired.

The discussions that took place during the IMTIG group meetings proved to be the most valuable aspect of the project. All participating teachers commented that they benefited from the opportunity to talk with fellow teachers about their classroom experiences, teaching ideas and resources, and concerns and problems about the use of new resources in their classrooms. The sense of community that developed within the IMTIG group likely would not have occurred without the longer duration of the project. By the second meeting, teachers were much more open with each other and were willing to share their concerns and questions. Teachers helped to support one another by recommending ideas, resources, and answers to questions; each teacher was an equal participant in the group. This collaboration among teachers provided a place where teachers were able to learn from each other.