IMPLEMENTING PROFESSIONAL DEVELOPMENT: A CASE STUDY OF MATHEMATICS TEACHERS USING INQUIRY IN THE CLASSROOM CONTEXT

by

Heather Renee Mathison

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Dr. Jennifer L. Luebeck

Approved for the Department of Mathematics

Dr. Kenneth L. Bowers

Approved for the Division of Graduate Education

Dr. Carl A. Fox

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DEDICATION

To my husband, Mark - Eternal thankfulness for supporting me through the laughter, the tears, and the many late nights – all while trying to complete your own dissertation. The light at the end of that tunnel is growing brighter every day.

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ABSTRACT

A body of research supports the use of inquiry-based instruction in science and its use has been advocated in mathematics, but mathematical inquiry remains ill defined and difficult to enact in the mathematics classroom. While helpful, simply valuing inquiry as a learning tool is not sufficient to enable teachers to implement it successfully with their students. In part, the trouble with using inquiry may arise from the fact that teachers received insufficient exposure to inquiry when they were students themselves.

The purpose of this case study was to examine how a sample of four teachers who participated in the Middle Grades Mathematics Project (MGM), an inquiry-based professional development opportunity, viewed inquiry and implemented it in their mathematics classrooms. In addition, this research attempted to identify influences that impacted how these teachers used inquiry. The four teachers selected for this study were identified due to interesting contrasts between their districts (urban vs. rural, traditional vs. reform text, level of involvement of fellow school teachers at MGM) and due to potential for comparison between the experience levels of the teachers within each district. Primary data collection occurred during the spring of 2008 and consisted largely of fourteen classroom observations for each teacher and a series of three semi-structured interviews. This data was supplemented by MGM program data and informal interviews.

The four teachers in this case study showed that they had distinctly different interpretations of mathematical inquiry. From their different interpretations, a number of consistent features of inquiry were identified. Mathematical inquiry was found to be a student-centered but teacher-guided experience where students built mathematical meaning and collaborated with one another to hone their ideas.

Despite their differing interpretations, all of the teachers acknowledged incorporating mathematical inquiry into their teaching after participating in the professional development. While the use of a reform text presented teachers with more lessons that the teachers felt could easily incorporate mathematical inquiry, the teachers that used a standard text were able to incorporate more mathematical inquiry into their lessons through designing lessons of their own or modifying lessons from outside sources.

CHAPTER 1

STATEMENT OF THE PROBLEM

Introduction

As evidenced by the aims of the *Principles and Standards for School Mathematics* (*PSSM*) published by the National Council of Teachers of Mathematics (2000), a shift has been occurring in mathematics education over the course of the past few decades. In order to better enable students to develop a deep understanding of mathematics, classroom teachers have been strongly encouraged to provide opportunities for their students to practice inquiry. In such a classroom, teachers are discouraged from providing their students with answers. Instead, teachers serve to facilitate and guide students as they seek their own answers. Such ideas are hardly new. The use of inquiry in the classroom emerged largely from the ideas of John Dewey nearly a century ago (National Research Council (NRC), 2000). He strongly argued against teachers merely presenting their students with knowledge. Only by struggling to grasp ideas for themselves did Dewey feel that students would be able to gain understanding.

> No thought, no idea, can possibly be conveyed as an idea from one person to another. When it is told, it is, to the one to whom it is told, another given fact, not an idea…. Only by wrestling with the conditions of the problem at first hand, seeking and finding his own way out, does he think. (Dewey, 1916, 159-160)

Inquiry requires students to actively build their own knowledge (Bruce, 2000; Piaget, 1973). Piaget states, "…every time the teacher gives a lesson instead of making the child act, he prevents the child from reinventing the answer." His constructivist ideas

provide a rationale for the use of inquiry in the classroom (NRC, 2000). Lincoln and Guba (2000) also view inquiry as a teaching method applied from a constructivist perspective. In their opinion, the active processes that require student engagement are critical for learning to take place.

Past reform movements with the aim of increasing the level of classroom inquiry were largely unsuccessful (West, 1990; Knapp & Peterson, 1991). Even when the curricula explicitly emphasized the use of inquiry, teachers struggled to use the materials as intended. One potential reason for the failure of past reforms of this nature rested in the lack of professional development provided to teachers. Faced with the expectation of making dramatic changes in their classrooms, teachers needed both training and support in order to effect these changes. When these needs were not met, teachers clung to their old methods of teaching their students. Now that the *PSSM* (2000) have placed a renewed emphasis on incorporating inquiry into mathematics classrooms, professional developers have been challenged to provide teachers with support in this endeavor. This study will examine how inquiry is employed in the classrooms of teachers who have been participating in a professional development experience based on inquiry.

Inquiry

While oft mentioned in education research, the term inquiry remains poorly defined (Anderson, 2002; Bulunuz, 2007). Although there are a number of similar definitions in use, no one definition has achieved widespread acceptance among teachers or researchers. According to Anderson (2002), different researchers vary their definitions according to the needs of their study. In reference to inquiry teaching, he declared, “This

broad category includes such a wide variety of approaches that the label is relatively nonspecific and vague" (p. 4).

One definition of inquiry used in a number of studies over the past decade was put forward in the National Science Education Standards (NSES) (National Research Council, 1996). According to the NSES,

> Inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations. (p. 23)

However, not even the National Research Council, the author of this definition, was entirely satisfied with it for classroom use. The council went on to further specify five features of inquiry in the classroom:

1. Learners are engaged by scientifically oriented processes.
2. Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions.
3. Learners formulate explanations from evidence to address scientifically oriented questions.
4. Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding.
5. Learners communicate and justify their proposed explanations. (NRC, 2000, p. 25)

While not unrelated to mathematics, inquiry takes on slightly different features in a mathematics classroom than in a science classroom. Mathematics is an essential aspect of scientific inquiry (NSES, 2000). However, experimentation is not used as commonly for constructing knowledge in mathematics as it is in science. Instead, in mathematics as in other subjects, students can build knowledge through exploration of topics and problem solving. This process is often referred to as "discovery learning," especially when the students actively engage in the process and make connections between their new knowledge and their existing knowledge base (Bicknell-Holmes & Hoffman, 2000).

Although the term 'inquiry' does not appear to any great extent in the *PSSM* (NCTM, 2000), the Learning Principle wherein "students must learn mathematics with understanding, actively building new knowledge from experience and prior knowledge" (p.11) represents the essence of the inquiry definitions identified previously. Glenda Lappan, former president of the NCTM, asserts that curricula written to support the goals outlined in the *PSSM* share the common feature of promoting classroom inquiry (2000). She further describes what she believes are necessary features of inquiry-based instruction:

- Engaging learners in problems in context
- Pushing learners' thinking while their exploration is proceeding
- Helping learners to make the mathematics more explicit during whole group interaction and whole group synthesis and summary

- Using and responding to the diversity of the classroom to create an environment in which all learners feel empowered to learn mathematics (p. 323)

Addressing Obstacles to Classroom Inquiry

With the new emphasis on using inquiry and other reform methods in the classroom, teachers are faced with redefining their roles in the classroom and implementing new strategies. However, research has shown that teachers will not change their practices just because they have been presented with a new curriculum or other educational materials (Manouchehri & Goodman, 2000; Thompson & Zeuli, 1999). Senger (1999) found that teachers' perceptions of the mathematics reform movement are crucial in determining whether the reforms will be successful. Similarly, in his synthesis Thompson (1992) found that teachers will resist making changes in their teaching unless they believe it will benefit their students.

Studies suggest that efforts to "teacher-proof" the curriculum by providing pre-packaged reform based materials are not successful (Manouchehri & Goodman, 2000; Powell & Anderson, 2002; Hawley & Rosenholtz , 1984). Research by Powell and Anderson indicates that even in the presence of a reform based curriculum, if a teacher's beliefs are opposed to the aims of the curriculum, then the resulting classroom instruction may not be reform based. In addition, a study that was completed for the U.S. Department of Education in the 1980s contained Hawley and Rosenholtz's strong assertion that teachers have more impact than the chosen curriculum.

> In virtually every instance in which researchers have examined the factors that account for student performance, teachers prove to have a greater impact than program. This is true for average students and exceptional students, for normal classrooms and special classrooms. (Hawley & Rosenholtz, 1984, p. 3)

On the other hand, even if teachers do express an interest in teaching by using inquiry or other reform methods, they may find that they are unequipped to do so either because they lack a sufficiently deep understanding of the mathematics that they teach or because they do not possess an adequate understanding of how to use reform methods (Cohen, 1990). Professional development can help to bridge the gap between teachers' traditional classroom practices and reform based instruction (e.g. Constantinos, Eliophotou-Menon, & Philippou, 2004; Loucks-Horsley, Hewson, Love, & Stiles, 1998; Borko & Putnam, 1995; Thompson & Zeuli, 1999). In their oft cited work, Loucks-Horsley et al. stated, "Given the many changes from typical practice in the United States, the implementation of reform-based curricular material must be accompanied by comprehensive professional development" (p. 413). Thompson and Zeuli took this statement a step further when they stated, "…professional development is key, if not the key, to the realization of the proposed reforms in subject matter teaching and learning" (p. 342).

Statement of the Problem

A body of research supports the use of inquiry-based instruction (e.g. Wise & Okey, 1983; Shymansky, Kyle, & Alport, 1983; Huveyda, 1994; Heywood & Heywood, 1992; Scruggs & Mastropieri, 1993). Students who learn through inquiry have been found to make larger gains in factors such as achievement and motivation than their peers

in more traditional classrooms (Shymansky &et al., 1983; Huveyda, 1994). However, inquiry-based learning is difficult to enact in the mathematics classroom. While helpful, simply valuing inquiry as a learning tool is not sufficient to enable teachers to implement it successfully with their students. In part, the trouble with using inquiry may arise from the fact that teachers received insufficient exposure to inquiry when they were students themselves.

Furthermore, teachers may suffer from the misconception that they are using inquiry in the classroom when in fact their students are merely playing with manipulatives and not gaining in conceptual understanding. Regardless of the definition of inquiry applied, there appears to be a consensus that student participation in hands-on activities does not necessarily mean that inquiry is taking place in the classroom (American Association for the Advancement of Science, 1993; NRC, 2000). If students are merely completing hands-on tasks without engaging or making any connections then inquiry is not being utilized (Wheeler, 2000). The NRC (2000) identifies the mistake of equating hands-on activities to inquiry learning as one of the top five myths surrounding inquiry. Similarly, Bulunuz (2007) states that anyone guilty of making this mistake possesses "a shallow understanding about scientific inquiry" (p. 22).

The purpose of this study was to examine how a sample of teachers who participated in an inquiry-based professional development opportunity viewed inquiry and implemented it in their mathematics classrooms. In addition, this research attempted to identify factors that influence how these teachers used inquiry.

The Middle Grades Mathematics project was a Montana initiative that encouraged the use of inquiry through providing teachers with strategies and allowing them to experience teaching with inquiry. This program provided a vehicle for the examination of inquiry-based instruction and its surrounding factors.

Research Questions

This study was designed around the following question related to teachers who were continuing participants in a content-based professional development program with an emphasis on inquiry-based instruction:

What are some of the ways that teachers who have experienced inquiry through professional development carry out inquiry-based instruction in the mathematics classroom?

1. In what ways do they operationalize inquiry-based instruction?
2. What influences affect their implementation of inquiry?

Significance of the Study

The results of this study have significance on multiple levels. On a practical level, the findings provides designers of the Middle Grades Mathematics project and other professional development experiences with insight into how well professional development experiences translate into daily teaching practice. More specifically, through the identification of motivating and obstructing influences that influence participant teachers' integration of inquiry into their daily teaching practice, this research

serves to inform professional developers about ways they can better support teachers with the implementation of inquiry. The identification of motivating and obstructing influences helps to meet a call from the National Mathematics Advisory Panel (2008) calling for research into how professional development translates into classroom practice.

On a more abstract level, this study serves to meet a need identified by Boaler (2002) and McClain and Cobb (2001) (as cited in Goos, 2004). The researchers called for others to pay more attention to the details of how reform approaches to teaching and learning are put into practice.

CHAPTER 2

REVIEW OF THE LITERATURE

The purpose of this chapter is to examine research into the implementation of inquiry in the classroom and into how professional development can provide teachers with necessary support as they endeavor to use inquiry-based instruction. This literature review begins with an examination of the effectiveness of inquiry as a teaching method and as a learning tool. Next, studies on how teachers use inquiry-based instruction with their students are discussed. The focus then shifts to an examination of research-based features of effective professional development and how these can help teachers to create lasting changes in teaching practice. Next, connections between professional development and inquiry, which overlap in this study and in the research literature, will be highlighted. Finally, an overview of the Middle Grades Mathematics project will be provided in order to give the necessary context for this study.

Inquiry

Effectiveness of Inquiry

A body of largely quantitative research supports the use of classroom inquiry (e.g. Wise and Okey, 1983; Shymansky, Kyle, & Alport, 1983; Huveyda, 1994; Heywood & Heywood, 1992; Scruggs & Mastropieri, 1993). Wise and Okey performed a quantitative study and found an effect size of 0.4 in favor of inquiry teaching methods. In addition, Shymansky et al. performed a quantitative study to determine the

effectiveness of a science curriculum designed to support the use of inquiry. In their work, they found large effect sizes (on variables such as cognitive achievement, process skills, and attitudes of the students) supporting the use of the inquiry-oriented curriculum. While performing an experiment on biochemistry students at a university in Turkey, Huyveda found that students in the group that was taught using inquiry methods outperformed students in the control group. Although Heywood and Heywood did not find that students who had participated in inquiry based classroom activities outperformed their counterparts in a control group, they did find that students in the inquiry group were more motivated to learn than their peers in the other group. Scruggs and Mastropieri focused their research on students with learning disabilities. Their findings showed that inquiry teaching was more effective with students than the more traditional methods revolving around learning from the textbook. These studies tend to support the idea that inquiry has the potential to play an important role in mathematics classrooms.

Anderson (2002) noted that in recent years research on inquiry has moved away from whether or not inquiry is effective in the classroom. After reviewing available literature, he claimed researchers are currently more interested in how to put inquiry teaching into practice in the classroom and in more fully understanding the details of how inquiry works. The next section reviews studies on the implementation of classroom inquiry.

Implementing Inquiry

Traditionally, classrooms have operated on the notion of the teacher as the authority figure or the possessor of answers to all student questions; however, current reforms in education, which support the practice of inquiry, call for a new paradigm (Ball, 1997; Remillard, 1999). Now, the push is for teachers to think of themselves as facilitators or guides for their students as the children continue on their lifelong journey of constructing their own understanding of the world (NCTM, 2000; Cobb, Wood, Yackel, McNeal, 1992; Benson, 1997; Goos, 2004).

From results of their separate qualitative studies, Benson (1997), Goos (2004), and Richards (1991) described how students are hesitant to give up the comforting notion that their teacher is an expert in everything that they learn. In her dissertation on classroom assessment, Benson found that the students were dependent on their teachers to confirm whether or not answers were correct. She noted a particular case where a student had been able to solve a problem and was able to describe his thoughts in arriving at a correct answer. Yet the student was not confident in either the formula he used or his logical thought process, so he turned to the teacher as the ultimate authority.

Developing a classroom environment where inquiry occurs on a regular basis does not happen overnight (Richards, 1991; Goos, 2004). Richards noted how both he and his students had to go through a period of adjustment as they learned to navigate their new roles in the classroom. He warned other teachers that this period could last for several months. In her examination of a teacher's efforts to build a community of inquiry in his mathematics classroom in an Australian secondary school, Goos watched as the

classroom teacher gradually withdrew his support (as an authority figure) from his students. Since his students had previously been able to rely on their teachers to confirm answers, the children initially lacked the skills to be more self-reliant. However, as students became more able to justify their work and to create their own understanding, their instructor was able to slowly slip out of his former role and become more of a facilitator.

The Teacher's Role in Inquiry

As part of the process of moving toward a more student centered classroom, teachers tend to play a key role in the facilitation of discussion among their students (Leikin & Rota, 2006; Bulunuz, 2007; Goos, 2004; Richards, 1991; Cobb, Wood, Yackel, & McNeal, 1992). According to Richards, "discourse is the central feature of mathematical inquiry" (p. 32). He stresses that teachers need to be well prepared and to provide plenty of structure to the inquiry so that students will actively engage, ask questions, and delve into the task at hand.

The effective use of questioning by the teacher can be an important part of improving the quality of discussion (Leikin & Rota, 2006; Cobb et al., 1992). In their piece of collaborative research, Leikin, an outside researcher, documented the development of Rota, a second grade teacher who was trying to develop her ability to manage inquiry in her classroom. They videotaped three different lessons, each with several months in between, and documented both how Rota's actions and her students' actions developed. In the process of analyzing the data, transcripts of the three lessons were made and coded. In order to establish reliability, Leikin and an independent

researcher both coded a particular ten minute portion of the transcript, achieving an inter-coder reliability of 84% and reaching consensus on the remaining 16%. As a result of their study, the authors found that the organization of Rota's lessons improved as evidenced by more defined periods of introduction, inquiry, and summative discussion. Rota's growth in the use of questioning was associated with the students' shift from stating facts in response to her queries to constructing "logical chains" (wherein students were able to logically explain their thought processes). The researchers noted that the students' ability to learn using inquiry methods improved as Rota became more adept at managing the inquiry based lessons.

Cobb, Wood, Yackel, and McNeal (1992) used videotapes of a lesson on place value in two different elementary mathematics classes in order to distinguish between a typical classroom and one with a focus on teaching for understanding. The two selected lessons were chosen from a larger body of videos since they covered similar material, utilized the same manipulatives, and provided the contrast desired by the authors. In particular, the authors saw that in the classroom where teaching for understanding was not emphasized, the teacher was not asking the students to justify their answers or to interpret them. In the rare case where justification was asked for by a confused student, a description of the steps of an algorithm was considered sufficient even though there was no real understanding involved. Students who made mistakes or requested more justification were temporarily ostracized until they corrected their ways. In the classroom where understanding was a priority, the teacher had started the year encouraging the students to question and challenge each other. By the time of the videotaped lesson later

in the year, the students regularly engaged in these activities. Making mistakes and asking questions developed into a normal facet of the classroom environment.

As demonstrated above, the attitude and behavior of the teacher has an enormous influence on the success of changes to curriculum and practice, including the effectiveness of new pedagogical strategies such as inquiry. To nurture self-efficacy and confidence about the content they teach and the best ways to teach it, teachers need high-quality professional development as described below.

Professional Development and Inquiry

At the time when researchers were calling for the increased availability of professional development for teachers, the poor quality of many existing professional development programs was also acknowledged (Sparks & Loucks-Horsley, 1989; Loucks-Horsley, et al., 1998; Hilliard 1997, Cohen & Hill; 1997). Typically, professional development activities lasted only a few hours and failed to engage the teachers. They also tended to be superficial and there was a lack of continuity between professional development opportunities. Due in part to these weaknesses, teachers' participation in professional development often did not translate into change in practice.

In response, a body of research into professional development was produced (Hawley & Valli, 1999; Loucks-Horsley et al., 1998), and researchers attempted to identify the characteristics of effective programs. While certainly not the only model of quality professional development, Hawley and Valli reviewed existing literature and identified eight essential features of professional development: 1) Professional

development should be built to meet the needs (not necessarily the desires) of teachers; 2) Whenever possible, teachers should be involved in the development of particular professional development opportunities; 3) Whenever possible, professional development should be set in a teachers' own school and related to the daily experiences of the teacher; 4) Teachers should be provided with plenty of opportunities to collaborate in their efforts to problem solve; 5) "Professional development should be continuous and ongoing" (p.141). It should be sustained over time if lasting changes are to be made; 6) The professional development should be evaluated using multiple methods in order to best gauge its effectiveness; 7) Teachers should be given plenty of opportunities to improve their own theoretical understanding; and 8) While goals may be small at first, the professional development should be one facet of a larger plan to enact change in schools.

In examining Hawley and Valli's model (1999), it is worth noting how the features support the notion that teachers should be practicing inquiry into their own teaching through such actions as delving into their teaching experiences, collaborating with their peers, and helping to develop their own professional development experiences. Just as inquiry-based learning can benefit students, participating in inquiry may enable the teachers to develop a deeper understanding of the subject they teach and of their students.

Although their approach is different, Thompson and Zeuli (1999) have identified their own five-point model of "transformative" professional development. They focus more on the need to disrupt the "equilibrium between teachers' existing beliefs and practices on one hand and their experiences with subject matter, students' learning and

teaching on the other" (p.355). The model revolves around the ideas of disrupting teachers' equilibrium and then providing them with plenty of opportunities to establish a new equilibrium before restarting the cycle. Teachers need to be given ample time to undergo their transformations and to be well supported throughout the process. This notion of taking time to readjust and better understand the connections between beliefs, practices, and experiences contains features of inquiry similar to those seen in the previous model.

The Teacher's Role in Change

As a group, teachers are noted for being quite conservative in regards to changing their practice. By upsetting teachers' equilibrium, the goal is to make the experience "sufficiently powerful to immunize teachers against the conservative lessons that most learn from practice" (Ball and Cohen, 1999). Huberman (1993) described teachers as "artisans" or "tinkerers" who are loathe to abandon their old practices. Instead, teachers pick up a new practice here or there to modify their existing repertoire. However, in this age, when the goal is to make sweeping reforms in education, "tinkerers," who are largely responsible for enacting the reforms, make achieving this goal difficult.

Research backs the idea that high quality professional development can transfer into changes in teacher practice (Boyle, Lamprianou, & Boyle, 2005; Charles, 1999). Two years into a longitudinal study of the characteristics of effective professional development in England, Boyle et al. published preliminary results on the self reported changes in teacher practice that occurred after participation in professional development. Mathematics, English, and science teachers across the nation were asked to fill out a

survey identifying which of the following six teaching practices they had changed: planning, classroom management, teaching style, assessment, teacher collaboration, or other (with specification requested). From the 509 surveys that were returned in 2003, the researchers found that teachers who had participated in professional development claimed to have made changes in an average of 3.23 teaching practices, whereas teachers who had not participated in professional development had only made changes in an average of 0.35 practices.

Supporting Teacher Change

Various studies cite the importance of providing support to teachers participating in professional development (Thompson & Zeuli, 1999; Ball and Cohen, 1999; Anderson, 2002; Charles, 1999; Constantinos et al., 2004; Joyce and Showers, 1995). Ball and Cohen write of the importance of building relationships between teachers and individuals outside of their schools who can serve as valuable resources. Examples of outside resources include people such as teachers in other schools or faculty at nearby universities. Constantinos et al. warn that teachers who are given poor support and little professional development will have difficulty in implementing a reform based curriculum since they have little help in progressing through stages of concern. Joyce and Showers note teachers' need for companionship as they embark on the potentially lonely journey of implementing changes in their classrooms. Without support, teachers are unlikely to persist in their efforts to implement inquiry.

Another oft cited feature of quality professional development is its sustained effect over time (Loucks-Horsley et al., 1998; Garet, Porter, Desimone, Birman, & Yoon,

2001). As noted by Garet et al., the time component refers both to the need for a large number of hours spent face to face with others who are participating in the professional development experience and to the need for the experience to be spread out over a period of time of significant duration. Implementing changes in classrooms takes time, and teachers need continued support from professional development throughout the process. In addition, professional development activities are more meaningful to the teachers if they have the opportunity to try new ideas in their classrooms and then to meet again later with their peers to reflect on the experience (Garet et al.). In the more traditional professional development models, where experiences last only a few hours or a day at most, teachers are denied this opportunity. Even within the context of a particular professional development session, teachers need to be given plenty of time to delve into topics and to explore them in their own way (Hawley & Valli, 1999).

Linking Professional Development and Inquiry

Charles (1999) performed what she describes as a phenomenological case study to examine the impact of a reform based professional development program for other professional development designers and facilitators. As a result, she found that "when one learns in a constructivist setting, there appears to be a greater chance of transfer to higher levels of use" (p. 86). After constructing their own knowledge about professional development, the designers were better able to use their knowledge effectively in their own professional development programs.

Ball and Cohen (1999) wrote of the need for professional development to evolve until it can consistently support teachers as they struggle to acquire the ability to better support their students in the quest for deeper understanding. Part of this evolution is a change in how professional development is designed. Borko and Putnam (1995) found that teachers must participate in professional development activities that deepen their own understanding in order to help foster deeper understanding in their own students. In a report on learning from 1999, the National Research Council took the stance that teachers learn in much the same way as everyone else. Therefore, just as inquiry methods work well for improving the understanding of their students, learning through inquiry is an effective design for the professional development of teachers.

In their study described earlier, Boyle, Lamprianou, and Boyle (2005) found that teachers who had participated in research or inquiry-based explorations into teaching reported a change in an average of 3.41 of their teaching practices – more changes than from any of the other types of professional development activities. Inquiry into teaching can manifest itself in a variety of ways, including but not limited to the analysis of classroom documents, action research, designing a curriculum, or the scoring standardized test items (Ball and Cohen, 1999). Schoenfeld (1985) found that the various approaches of practicing inquiry about teaching were closely linked with how inquiry is used for learning in the classroom (in Jaworski, 2003). In an extension of the adage that teachers teach how they were taught, it should make sense that practicing inquiry and learning through inquiry would better enable teachers to implement inquiry into their own classrooms.

Student Outcomes

There is a lack of definitive research on the existence of a clear link between the professional development of teachers (whether on the topic of inquiry or otherwise) and the mathematical performance of their students. Studies that attempt to establish such a link are not common and have tended to fail in finding marked improvement in student achievement after a teacher has participated in a mathematics professional development program (e.g. Diaz-Santana, 1993; Meyer, Sutton, 2006; Hanssen, 2006). Perhaps one reason for the lack of a clear relationship is that the assessments typically used to measure achievement are more traditional standardized tests that may be poor measures of the deeper understanding inquiry-based learning experiences are intended to construct.

While a direct link between professional development and student performance remains elusive, there is still the possibility of connecting them through teachers' pedagogical content knowledge (PCK) or mathematical content knowledge. Research has shown that professional development can improve a teacher's PCK and augment her content knowledge (Fan, 1998; Weisner, 1989). Researchers have also identified that content knowledge and the PCK of the instructor impact student performance (Hill, Rowan, & Ball, 2005; Harbison & Hanushek, 1992; Rowan et al., 1997). Given these findings, an indirect link is formed between professional development and student achievement in mathematics. This link is also proposed in Hanssen (2006).

Middle Grades Mathematics Project

The Middle Grades Mathematics (MGM) project was a professional development project involving 24 middle grades teachers in schools from west central Montana, focusing on mathematics content in two critical areas: geometry and algebraic thinking. The project strove to improve the achievement of middle grades mathematics students in the partner schools by increasing teachers' content knowledge and providing them with strategies to help students understand mathematics on a conceptual level. Highlights of the project objectives were:

1. Increase the standards-based content knowledge of middle school teachers, including an emphasis on content standards addressing geometry and algebraic thinking.

2. Develop teachers' ability to implement and facilitate inquiry-based learning (teaching through problem-based learning, designing and facilitating student investigations, and appropriately using technology and hands-on materials).

3. Increase teachers' ability to integrate technology into classroom instruction, with the goal of using technology to support conceptual understanding of worthwhile mathematics.

4. Develop middle school mathematics "learning communities" both within and between schools, and promote collaboration and shared expertise between schools.

To build anticipation and establish instructional norms for the upcoming summer institute, a two-day Middle Grades Mathematics "launch meeting" was held in February 2007. Participants came to the site of the summer institute to experience the lakeside setting and facilities, learn about project goals and expectations, meet the four instructors,

develop a shared understanding of inquiry in mathematics, compare curricula, and experience two inquiry-based lessons. Participants also were introduced to the software platform that supports their Internet-based communication during the academic year.

In July 2007, 24 teachers participated in a two-week summer institute (one week for geometry, one week for algebraic thinking). Each week was led by a university mathematics educator and a master middle school teacher. The instructors collaborated to frame content instruction with appropriate classroom references and examples. The institute emphasized mathematics content and learners' interaction with the content through inquiry-based learning to help participants develop pedagogical expertise and confidence in each of the content areas.

Academic year follow-up focused on development, implementation, and reflection on lessons that incorporate the content of the summer workshops as well as inquiry-based instruction. Each teacher composed an individual "action plan" describing how and when they intend to implement the knowledge gained during the summer institute, including their goals for using inquiry-based instruction during the academic year 2007-08. An online discussion, with topics changing each monthly, is ongoing through the year and enables continued learning and collaboration among partner schools and teachers.

Most significantly, instructional coaching is built into the academic year program. Each teacher will receive two observation visits per semester, with a minimum of two hours per visit. Site visits are conducted by university faculty and master teachers; each coach is assigned to a set of participants whom they will visit consistently in order to

facilitate the building of trust relationships. Site visit activities include lesson observations and coaching sessions; observation and modeling of inquiry-based lessons; teacher exchanges, and other collaborative activities.

Summary

In this era where quality mathematics teaching is often equated with standard-based instructional materials and strategies, increased emphasis has been placed on using inquiry in the classroom (NRC, 2000; NCTM, 2000). In classrooms where inquiry is practiced on a regular basis, students are actively engaged in the learning process—asking questions, making justifications, communicating mathematically, and building their own knowledge in the process. The teacher does not provide students with answers but, rather, guides students so that they are able to discover the answers to questions for themselves.

Most teachers are not equipped with the necessary skills to teach using inquiry methods. These teachers need professional development in order to develop their abilities. This professional development should be sustained over time, closely tied to what the teachers actually teach in their schools, and designed to incorporate many of the same inquiry methods that teachers will ideally use with their students. Through experiencing inquiry as learners themselves, teachers become better able to provide inquiry-based learning experiences for their own students in the classroom.

The research literature has established the value of inquiry-based instruction; it indicates the importance of professional support if teachers are to successfully implement

inquiry-based instruction; and it has identified key elements of effective support. The study described in the following chapter draws on these three areas in its treatment, its methodology, and its interpretation of findings.

CHAPTER 3

DESIGN AND METHODS

Research Questions

A primary research question along with two sub-questions guided the development of this study. They are repeated here.

What are some of the ways that teachers who have experienced inquiry through professional development carry out inquiry-based instruction in the mathematics classroom?

1. In what ways do they operationalize inquiry-based instruction?
2. What influences affect their implementation of inquiry?

The first sub-question largely dictated the design of the study. A substantial portion of data collection revolved around developing an accurate picture of how teachers went about the ill-defined task of implementing inquiry in their classrooms and of how they practiced decision making as episodes of inquiry unfolded. The second sub-question focused on identifying factors that influenced the implementation of classroom inquiry.

Research Design

This study employed mixed methodologies. While the bulk of collected data is qualitative, some of the background data was quantitative in nature. The quantitative measures included pre- and post-test scores on two tests measuring growth in

mathematical content knowledge after the two-week summer institute. In addition, a survey assessing teachers' self-efficacy in teaching mathematics and expectations for student learning was given as a pre-test in Summer 2007 and again in Summer 2008. This information provided background information on the teachers in the study but did not serve to answer the research questions.

A case study approach was used to address the questions at the heart of this research. According to Merriam (1998),

> A case study design is employed to gain an in-depth understanding of the situation and meaning for those involved. The interest is in process rather than outcomes, in context rather than a specific variable, in discovery rather than confirmation. Insights gleaned from case studies can directly influence policy, practice, and future research (p. 19).

Since the primary purpose of this study was to examine how teachers implemented inquiry in the mathematics classroom, the focus was not on improved student achievement and understanding (an outcome) but rather on the journey wherein the teachers made choices on a daily basis regarding how inquiry was utilized.

Merriam also stated that, "Case study has proven particularly useful for studying educational innovation [and] for evaluating programs" (p. 41). For this research, the educational innovation was the use of inquiry-based instruction, and the study itself served as one of many different measures for evaluating the professional development program from which the teachers' innovation stems.

According to Creswell (1998), "a case study is an exploration of a 'bounded system' or a case (or multiple cases) over time through detailed, in-depth data collection involving multiple sources of information rich in context" (p. 61). In this study, three

fifth grade teachers and one fourth grade teacher who participated in the MGM professional development experience served as the cases to be studied in their mathematics classrooms over the course of a semester.

Sample

Four teachers and their classrooms were included as cases in this study to gain as accurate a picture as possible of mathematical inquiry in each locale. Each of the teachers served as an individual case. The selection of four individuals for this study was supported by Creswell who stated that case studies of this sort typically consist of more than a single individual but no more than four individuals (1998).

Unlike quantitative research where random sampling is typically preferred, the participants in this study were "purposefully" selected from the pool of participants in the professional development experience. In this study, the subjects form a "typical sample" as they are representative of their counterparts in the professional development experience (Merriam, 1998). The choice of subjects was guided both by limits of feasibility and by the desire to select "parallel" cases within and between schools that could be compared and contrasted. The particular teachers were identified with input from the program director, summer institute instructors, and academic year coaches.

Originally, all of the participants were supposed to be fifth grade teachers. Two of them were at Adelaide Elementary School in Adelaide while the other two taught at Bartleby Elementary in Brisbane. The Middle Grades Mathematics project served a total of 24 teachers, but the participants were concentrated in three communities. One of the

three communities was eliminated as a potential case source as it was sufficiently far away from the researcher to preclude regular visitation. However, the remaining two towns were particularly favorable locales both due to convenience and due to the contrasts between them.

Adelaide was comparatively rural by Montana standards (pop. 2,000) while Brisbane was in one of Montana's larger cities (pop. 35,000). Elementary and middle school students in Adelaide used *McGraw-Hill Mathematics* (2002), a traditional textbook series, while Brisbane utilized *Everyday Mathematics* (University of Chicago School Mathematics Project, 1997), a reform based curriculum that incorporated inquiry into the lessons.

Another element of contrast was the support system available to each subject. A total of five MGM participants spanning grades 5-8 worked in the Adelaide district and taught almost all mathematics classes in those grades, thereby allowing for more of a "team" approach to experimenting with inquiry. In contrast, the subjects in Brisbane had only one other MGM participant at their school.

Originally, pairs of teachers were identified from each town in order to better distinguish both their similarities and differences. It was expected that these would serve to better illuminate the external and internal factors that influenced the use of inquiry in the classroom. Furthermore, selecting pairs of teachers from each school served to reduce confounding factors and to better illuminate the true characteristics of each school and the unique characteristics of each classroom. In a fortuitous coincidence, the two teachers at each school would have enabled a comparison between experienced and

novice teachers, as one teacher from each school was relatively new to teaching while the other had more than a dozen years of experience.

The two teachers assigned as case studies from Bartleby Elementary were the only two who participated in MGM. This was not true in Adelaide which had three participating fifth grade teachers. The Adelaide teacher who was not selected was eliminated due the small size and unique demographic of her mathematics class, which would have introduced confounding variables into the study.

When asked to participate in December of 2007, all four selected teachers agreed to participate. However, Ms. McClure, one of the teachers at Bartleby Elementary in Brisbane informed the researcher that she was teaching fourth grade not fifth grade. This event was unanticipated; while she had taught fourth grade during the 2006-2007 school year, Ms. McClure had been accepted to MGM with the understanding that she would be teaching fifth grade the following year. Although Ms. McClure was not teaching fifth grade, the researcher consulted with her advisor and decided to keep her in the study as the other MGM teacher at the school had already agreed to participate and as fourth and fifth grade classrooms were not deemed to be so dissimilar as to be incomparable.

To further complicate matters, the fifth grade teacher at Bartleby Elementary in Brisbane decided to withdraw from the study in mid-February. She did so for personal reasons having nothing to do with this study or the researcher. However, as this teacher was going to be unexpectedly out of the classroom for a large part of the spring, the researcher would have had to replace this teacher even if she had not chosen to withdraw. As the study was already underway, the researcher chose to continue visits to Ms.

McClure's classroom even though there was no other MGM participant teacher at the school. Therefore, comparing two teachers within that school became impossible. However, in order to maintain other aspects of contrast (town size, curriculum, experience level of the teacher), Ms. Fowler, another fifth grade teacher from Brisbane albeit from Brookings Elementary, was selected to participate. Her school used the same textbook as Bartleby Elementary and her experience in the classroom was similar to the teacher who withdrew from the study.

Setting

While the participants were linked by their participation in the Middle Grades Mathematics professional development experience, this case study does not focus on that context, but on the individual classrooms of the selected teachers. Two of the fifth grade classrooms were located at the same elementary school in Adelaide, a largely rural school, with class sizes of fewer than twenty students. The mandated mathematics curriculum (in the form of the *McGraw-Hill Mathematics* textbook) was very traditional. The other two classrooms were situated at elementary schools in Brisbane. Both schools were comparatively urban, with class sizes of closer to twenty-five students. The elementary schools in Brisbane use a reform curriculum, *Everyday Mathematics* (University of Chicago School Mathematics Project, 1997), which was in its first year of adoption for all elementary schools in Brisbane after many years of using a traditional textbook series.

Researcher

According to Bogdan and Biklen (1992), the researcher is the "key instrument" of data collection in qualitative research. In this study, the researcher was a doctoral student in mathematics education. She had a master's degree in mathematics and eight years of teaching experience at the college level. While she had two years of experience working with individual elementary school students, she was not a certified teacher and had never had her own fourth or fifth grade classroom.

The researcher was an advocate of reform-based mathematics. However, rather than passing judgment on the participant teachers' implementation of inquiry, the researcher focused on understanding each teacher's perspective. She strove to remain impartial in the classrooms and generally refrained from offering pedagogical advice or otherwise attempting to influence instruction. She did, however, on occasion answer questions about mathematical content when asked by the teachers (e.g. What answer did you get for this question?).

The researcher had begun to build trust with these teachers prior to the study and she tried not to violate or erode that trust during classroom observations and interviews. In February of 2007, she participated in the two day "launch" of the MGM project. She was also present for four days of the MGM summer institute. For both experiences, the researcher was a full participant in the teachers' activities and never took on the role of an authority figure. She strove to continue to build trust with these teachers over the course of data collection by minimizing her interference in the classroom and through her genuine interest in learning from them.

The researcher did have connections to the MGM project. Her research advisor was the director of the professional development program, and the MGM evaluator also sat on her committee. In addition, the researcher was employed by MGM as an assistant during the course of data collection. However, the research conducted in this study was separate from her MGM responsibilities.

Data Collection

Teachers were asked to participate in this study at the end of the summer of 2007. However, the bulk of the data collection took place from late January through early May of 2008. The rationale for collecting data at this time rested on the desire to examine how teachers typically went about implementing inquiry in their classrooms. At the point of data collection, teachers had been in the classroom for a full term after participating in the MGM summer institute. The novelty of using inquiry had largely worn off and there was a greater likelihood of gaining an accurate picture of each teacher's use of inquiry on a regular basis. An overview of the timeline for this study is presented in Table 1.

Before any data collection took place, consent forms were acquired from all participants. As shown in Appendix B, participation in this study involved a number of commitments from the teachers. These expectations were identified for the teachers from the outset in order to reduce the possibility of misunderstanding. In appreciation for their willingness to participate, teachers were occasionally given small tokens of gratitude such as gift certificates to local stores.

Table 1. Data Collection Timeline

Date	Actions to be Taken	Research Questions Addressed
Dec. 2007 or early Jan. 2008	Contact participants and administrators Distribute consent forms Conduct initial interviews (face to face)	Q2
End of January – Mid-May 2008	Weekly: Observations of mathematics lesson in each classroom	Q1, Q2
	Weekly: Post-observation "snapshot" interview on use of inquiry	Q1, Q2
	Weekly: Journal reflections by teachers	Q1, Q2
	Ongoing: Interpretation of program data Ongoing: Iterative data analysis	
Mid-March 2008	Factors Interview	Q2
Mid-May 2008	'Is It Inquiry?' Interview	Q1
July 2008	Project Impact Survey	Q1
Summer 2008-Summer 2010	Continued Data Analysis	

In addition, consent forms were sent home with students in the hope of gaining permission to videotape Adelaide teachers' mathematics lessons. Parents were asked to grant their consent as a precaution. Most students did not return their slips but this was in accordance with the district's policy that consent was implied unless the parents stated otherwise. While the researcher's interest lay in the decision- making processes and behaviors of the teacher, students were inevitably taped in the process of capturing the teachers' facilitation of inquiry activity. Students are not referenced directly in the study. Despite initial plans to videotape all four classrooms, students in Brisbane were not recorded as the local superintendent did not grant permission for videotaping in those schools.

Once collected, all data was stored in a locked office in order to protect the privacy of the participants. Pseudonyms were also assigned in order to help ensure the anonymity of the teachers and their students. No one viewed the data aside from the researcher, her advisor, and occasionally the teacher who was the source of the data. Teachers were specifically advised that their MGM coaches would not be given access to any data from this study.

Collection of data from multiple sources helped to ensure the ability to provide the thick, rich description that typifies case studies and is particularly important in helping to address the issues of reliability and validity in qualitative research (Creswell, 1998). The results from these different methods of data collection were compared and contrasted in an effort to triangulate the findings and ensure that the data drawn from different sources should all support each other (Merriam, 1998; Creswell, 1998). The primary methods of data collection in this study included classroom observation, interviews, journals, and program data. Each of these methods will be detailed in the following sections.

Observation/Videotaping

Classroom Visits. The researcher made regular visits to each classroom to gain a more accurate view of both the classroom context and a "typical" mathematics lesson for the teachers and students. While the primary source of data lay in observing the mathematics lesson, the researcher did not confine her visits simply to the period of mathematics instruction. Staying for a longer period of time provided contextual information and minimized disruption to the classroom. Also, the informal "snapshot"

discussions and reflective interviews were easier to facilitate with the teachers if the researcher was flexible. In practice, the researcher spent an additional thirty minutes to an hour in each classroom due to breaks in mathematics instruction (usually for recess, music, library, or physical education). During this time, the teachers would typically prep for class or attend to other responsibilities although they did talk with the researcher at times. The only exception to this was in Ms. McClure's classroom where math was taught in one seventy-five minute session. Ms. McClure had lunch before math class and recess duty afterward, so the researcher found that staying more than a few minutes beyond the beginning or end of math class was neither practical nor greatly appreciated.

Ideally, each classroom would have been observed once a week on a regular schedule, with minor variations to avoid testing days or to observe a particular lesson. The reality of elementary classrooms made a set visitation schedule impossible. Every week of the study consisted of different visits on different days because of field trips, tests, assemblies, early release days, teacher absences, and even student behavioral issues that prevented math instruction. This issue is addressed again later.

Videotaping. The original plan was to alternate between videotaping and personal visits by the researcher to each classroom. Weekly visitation was not expected to be problematic in Brisbane. However, the fifth grade teachers in Adelaide taught mathematics at the same time of day. Since distance made traveling to Adelaide twice a week prohibitive, videotaping was deemed necessary. However, Brisbane administrators would not permit videotaping. Therefore, Brisbane classrooms were each personally observed once a week while Adelaide classrooms were personally observed every other

week. On typical visits to Adelaide, the researcher observed one of the teachers after setting up a video recorder to tape the mathematics lesson of the other teacher.

On each day she was recorded, the videotaped teacher was asked after class whether or not she believed inquiry had occurred and her comments were recorded (along with her name so as to avoid confusion) at the end of the set of fieldnotes for the other Brisbane teacher. The teacher's comments from that day were transferred to the set of fieldnotes corresponding to her lesson on that day after the video had been watched.

Although less time was spent observing in each of the Adelaide classrooms, the researcher felt that her relationship with each of the teachers at Adelaide Elementary did not suffer because she continued to interact with the teacher who was being videotaped during breaks and after school. In fact, the researcher deemed her relationship with both teachers in Adelaide to be comparatively stronger than her relationship with Ms. McClure at Bartleby Elementary, who did not have a break during math instruction or directly afterward.

Observation Protocol. An observation protocol was made using items from the Reformed Teaching Observation Protocol (RTOP) which was designed to capture the level of reform-based instruction in mathematics and science classrooms (Piburn, Sawada, Falconer, Turley, Benford, & Bloom, 2000). The protocol was used for all classroom observation whether done in person or by videotape (a copy of the protocol can be found in Appendix C). While the RTOP itself was not deemed appropriate for this study, Henry, Murray, and Phillips (2007) performed a factor analysis on the RTOP and identified specific items which loaded onto inquiry. The identified items were included

as the first five items on the observation protocol in Appendix C. Five other items from the RTOP were also included as they used words such as "engaged," "hypotheses," and "manipulatives," which had been discussed by teachers at the MGM 2007 summer institute. While not technically using the RTOP, the researcher did complete an online training on the use of the RTOP at a Web site maintained by Buffalo State University of New York in the hope of using her own protocol more effectively.

Interviews

Both semi-structured and informal interviews were utilized in this research. The semi-structured interviews were recorded and then transcribed in an effort to capture teacher statements accurately, to preserve the quality of the information obtained, and to allow for easy access to the data for the constant comparison process. Data from informal interviews and "snapshot" conversations were recorded in field notes.

Semi-Structured Teacher Interviews. Each teacher was asked to participate in an initial introductory interview shortly after classroom observations began. This interview provided the researcher with necessary background information, including the teachers' experience in the Middle Grades Mathematics (MGM) project, their experiences with inquiry-based instruction during the fall semester, and contextual data about their teaching experience, classroom routines, and school/district setting. At this time, researcher and teacher also discussed the logistics of this case study. The interview lasted between sixty and ninety minutes. The protocol for this interview is attached as Appendix D. This interview laid the groundwork for the narrative on the particular cases.

Originally, regular reflective interviews were planned to occur approximately every three weeks and expected to last about thirty minutes. These interviews were intended to provide an opportunity for elaboration on topics that arose from the more frequent "snapshot" interviews, from observations, or from teacher journals. In reality, scheduling interviews was a very difficult process. Due to the hectic schedules of the teachers, it took nearly a month for all of the introductory interviews to take place. Therefore, it was decided to try and keep other interviews to a minimum. Instead, the researcher found herself able to ask questions about lessons and journals as they arose in a more informal manner.

Two additional interviews were conducted with slightly different aims. At the end of data collection, there was an interview focused on the teachers' interpretation of inquiry. At the mid-point of data collection, an interview focused on influences that the teacher perceived to impact her use of inquiry in the classroom. Some of the questions in this interview addressed factors identified in the Inside the Classroom Observation and Analytic Protocol by Horizon, Inc. (2003).

Informal or "Snapshot" Teacher Interviews. After each classroom observation, the researcher added the teacher's perspective to the observation data by asking the teacher whether, in her view, the day's lesson involved inquiry. If so, she was asked to briefly describe how; if not, she was asked whether she believed the day's lesson could support the use of inquiry. The intention of these interviews was to enable the researcher to better understand both the teacher's perceptions regarding the role of inquiry in her classroom and to identify influences that impacted the use of inquiry.

Before the first of these interviews, the teachers were advised that these questions would be asked on a regular basis; however, they should never be afraid to say that inquiry did not occur on a given day. The intention of these questions was not to push the teachers to use inquiry more than they otherwise would; therefore, the researcher routinely emphasized that lessons without inquiry were perfectly acceptable for observation.

Other informal interviews occurred on a regular basis. As mentioned earlier, in most cases, the researcher's visits overlapped with the teacher's planning time or other non-teaching time. This overlap enabled teachers to answer brief questions related to clarification of the lessons that were observed.

Journals

The teachers were asked to keep a weekly journal. However, rather than chronicling the events of an entire week of instruction, they were asked to describe a particular episode of inquiry from the past week that stood out in their mind (regardless of how successful the episode was). In the event that a teacher was unable to identify an episode of inquiry, she was asked to describe why no inquiry-based instruction occurred that week. An emphasis was placed on brevity in order to minimize the time commitment on the part of the teachers. Teachers were given the choice to keep their journals electronically or on paper according to their individual preferences, but all chose to keep them electronically via email. Per their request, the researcher emailed the journal prompt to the teachers at the end of each week to remind them about the journaling.

Textbooks

While the goals of this study did not include textbook analysis, the texts were referenced to provide context to the daily classroom instruction. Adelaide Elementary School used the *McGraw-Hill Mathematics* series (2002) while the teachers in Brisbane used *Everyday Mathematics* (2007). *McGraw-Hill Mathematics* belonged to the group of texts identified by Tarr et al. (2006) as "publisher generated." Publisher generated texts typically consist of two page daily lessons followed by worked examples and practice exercise. Reys et al. (2004) claimed that the mathematics in publisher generated texts was presented as a series of facts to memorize (2004) with little emphasis on depth of knowledge or connections to other topics. *McGraw-Hill Mathematics* was classified as a "traditional" text for this study as it was in the class of textbooks which traditionally dominated the textbook market.

In contrast, the series used in Brisbane, *Everyday Mathematics*, was classified in a distinct class by Tarr et al. (2006) identified as "NSF-funded" which arose from the fact that the curriculum had been developed at least in part using funds from the National Science Foundation. The University of Chicago School Mathematics Project (UCSMP) created *Everyday Mathematics* and its NSF funding was part of a charge to develop standards-based curriculum projects. Other curricula designed to meet this call at the elementary school level include *Math Trailblazers* and *Investigations in Number, Data, and Space* (Reys, 2001). According to Trafton (2001), these standards-based materials are written to be comprehensive, to be coherent, to develop ideas in depth, to promote sense making, to engage students, and to motivate learning. As such, the texts were designed to use strategies such as hands-on learning and classroom discussion. Lessons

were also designed to help students build connections between the different topics and to add depth to student understanding (Trafton, 2001). *Everyday Mathematics* was classified as a "standards-based" curriculum for purposes of this study.

Other Classroom Artifacts

The other classroom artifacts that were of primary interest in this study were textbook supplements, district curriculum and standards documents, and teacher prepared materials. The materials provided context for the daily instruction and played a role in how inquiry was implemented in each classroom. District standards and pacing guides, as available, were reviewed for similar reasons. Teacher prepared materials that were relevant to inquiry gave insight into the decision-making process that teachers used in planning their lessons.

Program Data

The program data were collected through the Middle Grades Mathematics project. This data included individual action plans submitted by each teacher, scores on pre- and post-tests of mathematical and pedagogical content knowledge for middle school, and scores on the Mathematics Teaching Efficacy Beliefs Instrument (MTEBI) attitude survey. These data served primarily as background information for the study.

Action Plan. While attending the MGM summer institute, each teacher was responsible for writing an individual action plan to be implemented during the 2007-2008 school year. As part of the plan, each teacher had to formulate a goal for using inquiry-based instruction in her classroom. The plan included a description of the steps to be

taken to achieve that goal as well as an explanation of how the teacher would measure his or her progress. This data source in particular revealed information about the teachers' perceptions of inquiry-based instruction and its implementation.

MTEBI . This instrument was initially written to measure the teaching efficacy beliefs and outcome expectancies of pre-service mathematics teachers. Enochs, Smith, and Huinker (1999) established the validity and reliability of this instrument after modifying it from an instrument on science teaching efficacy beliefs. The Middle Grades Mathematics professional development designers reworded the items slightly to make them relevant for inservice teachers (primarily through the changing of verb tenses from the future tense to the present tense).

Content Tests. As part of their participation in an intensive two week summer institute experience, MGM participants took a pretest and a posttest to measure changes in their mathematical content knowledge over the course of instruction. The test was written to assess the mathematical content and pedagogical content knowledge of middle school teachers by the Center for Research in Mathematics and Science Teacher Development (2006) and was established to be both valid and reliable. Two tests covering geometry/measurement and algebraic ideas were given to MGM participants. The tests consisted of multiple-choice items and free response items, including items that required teachers to analyze student errors and responses.

Project Impact Survey. This instrument, designed by the researcher and the project director, was given to all MGM participants during the summer of 2008. Each teacher

was asked to identify the features of the professional development program that had the greatest influence on his or her classroom practices. The data from this survey were analyzed by the researcher to identify the aspects of MGM that the teachers felt most impacted their use of inquiry in the classroom.

Data Analysis

During the period of data collection, interpretation of the data occurred on an ongoing basis using the constant comparative method developed by Glaser and Strauss (in Merriam, 1998). According to Merriam,

> The basic method of the strategy of the method is to do just what its name implies – constantly compare. The researcher begins with a particular incident from an interview, field notes, or documents and compares it with another incident in the same set of data or in another set. These comparisons lead to tentative categories that are then compared to each other and to other instances. (p. 159)

However, due to the quantity of data that was being generated, much of the data interpretations had to take place after the official observations ended. This interpretation continued at varying rates (depending on the researcher's other commitments) from the summer of 2008 through the summer of 2010. All documentation was coded using methods outlined in Bogdan and Biklen (1992) and varied depending on the data source. The data analysis for particular data sources will be detailed within this section.

Observation/Videotaping

Observational data was collected in the form of fieldnotes and the use of an observational protocol which will be referred to as the RTOPmod as it was modified from the RTOP developed by Piburn, Sawada, Falconer, Turley, Benford, & Bloom (2000).

Coding of the Fieldnotes. After the end of data collection, the fieldnotes were coded using codes which emerged from the 'Is It Inquiry?" Interview, which will be described in more detail later along with its coding process. The interview gave a detailed portrait of each teacher's view of mathematical inquiry, and the resulting codes from that interview helped to focus the analysis of the observations. This additional focus was needed as the fieldnotes contained information on over fifty classroom lessons, many of which had little to do with inquiry itself.

Analysis and Findings from the RTOPmod. While the scoring seemed fairly straightforward in training, the researcher struggled to use her own protocol in classroom visits. Her difficulty arose from the compound nature of many of the items. Consider the following example: "Students were actively engaged in thought-provoking activity that often involved the critical assessment of procedures." The researcher found scoring challenging when students were actively engaged in thought provoking activities that had limited critical assessment of procedures or when the activity was thought-provoking and involved critical assessment but was not particularly engaging to the students. The presence of the imprecise word 'often' was enough to warrant a Likert-scale even before considering whether students were engaged in thought provoking activity.

Despite concerns about the reliability of the protocol, data from an RTOPmod observation protocol (see Appendix C) that was completed after every observation were entered into a spreadsheet and descriptive statistics were run using Microsoft Excel. The RTOPmod was also used to identify the highest and lowest scoring observations as well as an observation that scored in the mid-range for that teacher. Appendix D contains

more detail on particular scores. These observations were identified by taking an average of the first five items on the RTOPmod as they were the items identified by Henry, Murray, and Phillips (2007) as pertaining to inquiry in a factor analysis of the RTOP.

The RTOPmod also served a purpose in that it helped to guide researcher observations. While the researcher would not claim reliability of the numerical data itself, comments made on the observation page (treated as part of the fieldnotes) provided useful information.

Videotaped Observations. In an effort to duplicate as much as possible the experience of observing the lesson in person, all videotapes, each containing a single observation, were watched once straight through without pausing or rewinding. While each videotape was dated and watched in chronological order, some were not watched until after the completion of the school year as priority was given to the in class observations. The tapes did present a few limitations in that blind spots in the classroom were unavoidable and some minor events were therefore missed. Close scrutiny of individual student work was not feasible and some student comments were not captured by the microphone. However, the tapes did capture the teachers' voices and most student comments as well as the details of lesson of the day and the manner in which teaching and learning were taking place in the classroom. Fieldnotes were taken while the videotape was being watched in the same manner that fieldnotes were taken in a personal observation. An observation protocol was completed immediately after watching the video. All coding and analysis was then performed on the fieldnotes as would be carried out in the case of the other observations.

Background and Influences Interviews

The Initial Interview and Factors Interview were both transcribed and coded along the margins. Compared with the "Is It Inquiry?" Intervew, the data from these interviews was of a more concrete nature and was, therefore, easier to analyze. In the background interview different colored highlighters identified key pieces of factual information about each teacher and her classroom. In the influences interview, color coding for different influences (e.g. time) was utilized along with the identification of other categories in the margins. Through the process of writing short pieces on each of the influences, the specific themes and categories emerged more clearly and were revised.

"Is It Inquiry?" Interview and Interpretation of Mathematical Inquiry

Conducted after all observations were complete, the "Is It Inquiry?" interview (or third interview) served a critical role in helping to clarify each teacher's personal understanding of inquiry. As all of the teachers were asked to discuss the inquiry content of the same group of activities, the interview was key in helping to clarify the teachers' individual perspectives on inquiry. Data analysis for this section as well as the subsequent section, entitled Interpretations of Mathematical Inquiry, was conducted at the same time. Therefore it is presented together here as well.

Originally the interview data were intended to be supported by lesson plans and journal entries. However, as formal written lesson plans consisted almost solely of the section number in the book to be covered (even in Adelaide where the teachers used the book for little else), lesson plans were not used as a formal data source. Similarly, as discussed in Chapter 3, the weekly reflections were exceptionally brief and contained

little data beyond what had already been collected in observations. Therefore, the primary support for the data from the interview came from observations and the informal interviews immediately following each of them.

Use of Spreadsheets. After transcription, information from the third extended interview was preliminarily coded along the margins to identify features of inquiry that emerged from each teacher's interpretation of the activities that she was shown. Initially, codes were drawn from the teacher's own language. Before any spreadsheets were made, all interviews were read and preliminarily coded. Then, a spreadsheet for each teacher was created in the order that their interviews had been conducted. Each row in the spreadsheet contained the themes and categories found in a particular quote as well as a unique identification number for that quote, the research question addressed by the quote, the teacher's name, the exact location in the data source, and the quote itself.

It was through the process of creating each individual spreadsheet that the true themes and categories began to emerge more clearly. The following examples are provided to demonstrate how codes were applied.

- Theme: Student Centered

Examples of quotes:

1. "It's letting the kids kind of engage in their learning *not just be told what an answer is."* (Baker)
2. "I did not get up and say, 'Well, guys, today you're going to multiply the base times the height.' They figured it out for themselves." (McClure)

3. "They'd come to it on their own without me telling them, 'Well, this is this and that's why.' You know, instead of lecturing to them." (Gilbert)

- Theme: Unsettled Definition

  Category: Personal Definition Change

  1. "I used to think it was more hands on at the beginning of the year." (Baker)
  2. "Maybe if you'd asked me in February I'd give a different answer." (Fowler)

  Category: Uncertainty

  1. "I don't one hundred percent know myself." (McClure)
  2. "I don't know. What the heck does inquiry mean?" (Gilbert)

Additional Analysis. Upon creation of a spreadsheet for a teacher, a one to two page description of each teacher's understanding of mathematical inquiry was also written. Ideally, member checking should have been conducted on these descriptions. This was not accomplished, in part due to the time lapse between when the descriptions were written and when the interviews were conducted.

In an effort to better capture each teacher's interpretation of inquiry, a diagram was created to provide a quick visual reference of the big ideas contained in the written description. As analysis proceeded, these figures were later revised and redrawn.

Iterative Process. Only after the creation of the two page description and supporting picture for the first teacher was the spreadsheet for the next teacher created. As each teacher's spreadsheet was constructed, an effort was made to not initially rely on previously constructed codes. Later, as analysis moved into comparing and contrasting,

the teachers' codes were further refined as appropriate. Similarly, early categories were replaced as more general or more accurate ones emerged through repeated analysis and increasing familiarity with the data. While new portraits were not written, codes continued to be refined even through the writing process as the data continued to reveal new information.

Once each teacher's views of inquiry had been constructed in this manner, the resulting themes and categories were applied to her fourteen observations and informal interviews in order to add support (or occasionally not) to the findings.

Journal

The journals were intended to provide a weekly snapshot of inquiry-based instruction from each teacher's perspective. In reality, the data from the journals was of limited use. While Ms. Fowler and Ms. Baker typically sent in their entries promptly, Ms. McClure and Ms. Gilbert both submitted the bulk of their entries over the summer after the completion of observations. All entries tended to be even briefer than expected and served primarily to inform the researcher that the teacher did not believe (or could not remember whether) inquiry occurred during a given week. Journal entries were in digital form; therefore, they were compiled by teacher, and read repeatedly. However, due to their extreme brevity, the journal entries were not formally coded or utilized as a data source.

Textbooks

As Tarr et al. (2006) established the distinctions between the *McGraw-Hill Mathematics* series (2002) and the *Everyday Mathematics* (2007) detailed analysis of the

textbooks was not completed. Instead they were used to provide background information on the classroom observations. In Brisbane, where lessons were typically straight out of the published materials, the text often provided a blueprint for the teachers' activities. In Adelaide, where the text was rarely used, the most used feature of the *McGraw-Hill Mathematics* text was the table of contents.

Program Data

Existing MGM program data was used to provide context to the findings of this study. In most cases, the analysis of the data had already been completed for the group of twenty-four teachers. The results from the four teachers in the case study were then compared with those of the entire group. Beyond the computing of descriptive statistics on DTAMS and MTEBI test results, no other statistical tests were run on the existing data.

Limitations

As Brisbane would not permit videotaping and Adelaide was sufficiently far away to make twice weekly visits impractical, the teachers in Adelaide were alternately observed and videotaped while the teachers in Brisbane were always observed in person. Other limitations included the use of Ms. McClure, a fourth grade teacher, rather than another fifth grade teacher as well as the inclusion of a teacher from a second school in Brisbane due to the loss of the first participant teacher from Brisbane.

Delimitations

As this was a qualitative case study, the results are not specifically generalizable beyond the four participant teachers. During classroom observations, the researcher attempted to remain at the "observer" end of the participant-observer spectrum. However, the researcher's presence and the frequent conversations about inquiry may have created a Hawthorne-like effect among the teachers in the case study. The other MGM participant teachers did not have anyone observing their mathematics classes on a weekly basis, nor were they routinely asked whether or not inquiry had been present in their lessons. The four teachers in this study may have implemented inquiry considerably more than the other MGM teachers simply because of the researcher's presence and the repeated opportunities to reflect about inquiry.

Summary

This case study examined how teachers who have participated in an extended, content-focused, and inquiry-based professional development experience implemented inquiry-based instruction and made decisions regarding the use of inquiry in the mathematics classroom. Influences that impacted their use of classroom inquiry were also identified. Particular attention was paid to aspects of the professional development experience that each teacher believed best supported her endeavors to implement classroom inquiry. A variety of data collection methods in the form of classroom observation, videotapes, journals, interviews, classroom artifacts, and program data

enabled the use of triangulation in data analysis and ensure the quality of this study's findings.

CHAPTER 4

RESULTS

For the benefit of the reader, the primary research question that guided this research is restated here along with its related sub-questions.

What are some of the ways that teachers who have experienced inquiry through professional development carry out inquiry-based instruction in the mathematics classroom?

1. In what ways do they operationalize inquiry-based instruction?

2. What influences affect their implementation of inquiry?

The chapter begins with background information on the Middle Grades Mathematics Program in order situate the four case study teachers within the larger professional development project in which they participated. The focus then shifts to a portrait of each of the teachers beginning with general descriptions of their classrooms and of their early understanding of mathematical inquiry. Next, the teachers' operationalization of inquiry is presented through analysis of classroom observations and teacher interviews. As part of this section, the influences that were identified by the teachers as impacting their implementation of inquiry are also detailed. Finally, individual portraits of the teachers' operationalization of mathematical inquiry, based primarily on a final semi-structured interview, will be described.

Findings from the MGM Institute

The teachers in this case study represent four of twenty-four teachers who participated in the MGM project. The goal of the project was to increase teachers' mathematics content knowledge and to demonstrate how inquiry-based learning can help students understand mathematics on a conceptual level. Highlights of the project objectives were:

1. Increase the standards-based content knowledge of middle school teachers, including an emphasis on content standards addressing geometry and algebraic thinking.

2. Develop teachers' ability to implement and facilitate inquiry-based learning (teaching through problem-based learning, designing and facilitating student investigations, and appropriately using technology and hands-on materials).

3. Increase teachers' ability to integrate technology into classroom instruction, with the goal of using technology to support conceptual understanding of worthwhile mathematics.

4. Develop middle school mathematics "learning communities" both within and between schools, and promote collaboration and shared expertise between schools.

Group Definitions of Inquiry

During the spring of 2007, teachers attended a weekend introductory workshop in order to provide an initial exposure to the yearlong project. On the first day of this workshop, the teachers as a group identified characteristics that they associated with mathematical inquiry. These features were then placed on the outline of a hand which

was hung on the wall where it served as an informal reference for the teachers whenever they all met as a group. A photo of this hand is included in Appendix A; however, it included the following characteristics: Engaged, Action, Student Centered, Questioning, Building Meaning, Connections, Applications, Discovery, Investigation, and Reflection. Teachers were not asked to memorize these characteristics. In later interviews with the case study participants, the teachers referred to "The Hand" in its entirety but did not recall the particular characteristics that it contained.

Appendix A also contains a number of definitions of scientific inquiry (rather than mathematical inquiry) and guided discovery which were generated through research. The teachers were presented with several of these definitions at the introductory workshop and with others at their next meeting during the summer. The definitions were used primarily for the purpose of generating discussion of their similarities, differences, and applicability to mathematics. Unlike "The Hand," the teachers in the case study were never heard mentioning these definitions once they had returned to their own classrooms.

The Summer Institute

In July 2007, the 24 teachers participated in a two-week summer institute (one week for geometry, one week for algebraic thinking). The institute was held at a remote lakeside learning center, allowing participants to immerse themselves in mathematics with few outside distractions. Each week was led by a university mathematics educator and a master middle school teacher. The instructors collaborated to develop active learning experiences framed by appropriate classroom references and examples. The institute emphasized mathematics content and learners' interaction with the content

through inquiry-based learning in the hope that the teachers would see the benefits of inquiry firsthand. While the teachers were engaged in learning through inquiry, they did not receive formal instruction on how to "teach" using inquiry. Instead, the teachers were largely left to their own devices as far as the identification of strategies used by the instructors which might transfer to their own classrooms.

As part of a more extensive end-of-project personal reflection, all MGM participant teachers completed a survey, the template of which is included in Appendix H. Of particular interest here was the following item: Which component of the MGM Project helped you the most with implementing inquiry in your classroom? Respondents were asked to select only one item and were given the following options: attending the 2007 summer institute, participating in online discussion during the year, designing and implementing an action plan, receiving personal coaching in mathematics, working with fellow teachers, and attending the 2008 Summer institute. The most popular response was participating in the 2007 Summer institute, which was selected by ten out of the twenty respondents.

Teacher Beliefs. The participant teachers in MGM completed the Mathematics Teaching Efficacy Beliefs Instrument (MTEBI) during the summer of 2007 and again at the end of the project in 2008. The instrument was developed by Enochs, Smith, and Huinker (1999) for preservice teachers and was found to be valid and reliable. The test was modified for MGM to be relevant for inservice teachers. The MTEBI measures both teachers' personal mathematics teaching efficacy (PMTE) and their mathematics teaching outcome expectancy (OMTE). Teaching efficacy relates to teachers' beliefs in their

abilities to perform certain behaviors in the classroom, and outcome expectancy relates to the teacher's belief that effective teaching will positively impact student learning. Of the twenty-one items on the MTEBI, twelve items measured the teachers' PMTE on a scale ranging from thirteen to sixty-five. The remaining eight items measured the teachers' OMTE on a scale from eight to forty.

A boxplot showing the pretest and posttest scores on the PMTE for all MGM participant teachers in shown in Figure 1. Similarly, a boxplot of their OMTE scores is presented in Figure 2. The range of scores attained by the four teachers in this case study is indicated by the dashed line in each of the plots. Note that none of the four teachers is an outlier. On both parts of the MTEBI, scores for the four teachers in this case study either increased or remained unchanged.

The two teachers from Adelaide scored in the first quartile on the PMTE component of the MTEBI; however, they each showed double digit increases in their scores bringing them into the middle fifty percent of MGM participants in the posttest. In contrast, the Brisbane teachers both scored above the median on the pretest's PMTE component, indicating a higher initial self efficacy, and their corresponding scores on the posttest changed very little. The self efficacy of the teachers was of particular interest as Czernisk (as cited in Enochs et. al., 1999) found that teachers with a high self efficacy were likely to use inquiry in their classrooms, while teachers with a low self efficacy were more likely to utilize teacher-centered strategies such as lecturing to students. The four teachers' outcome expectancies (as shown by the OMTE scores in Figure 2) were all below the median of the MGM participants at the time of the pretest.

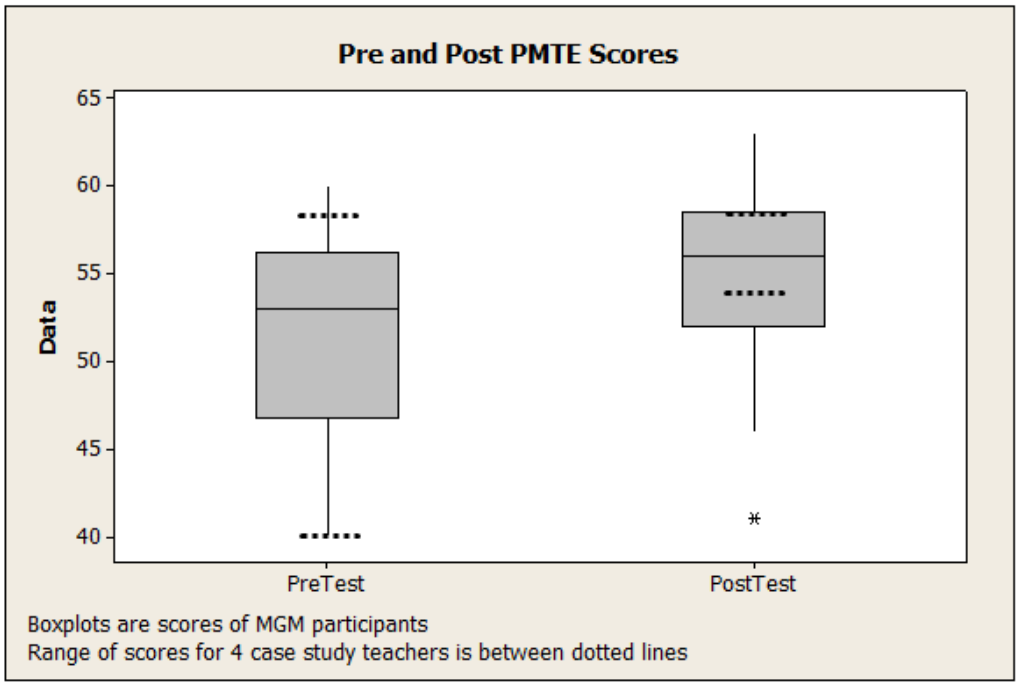


Figure 1. Pre and Post PMTE Scores

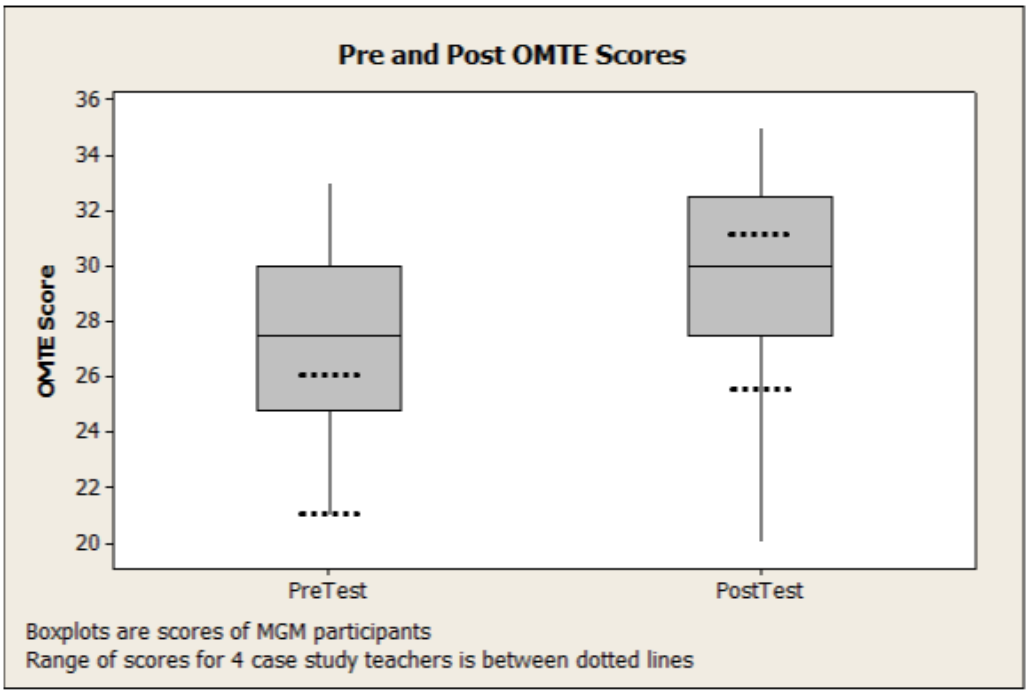


Figure 2. Pre and Post OMTE Scores

However, all four teachers showed increases in their outcome expectancy. Baker, in particular, showed a large change in outcome expectancy as evidenced by an increase in her score of over ten points out of forty.

Content Knowledge. All participants of MGM completed Diagnostic Mathematics Assessments for Middle School Teachers (DTAMS) in the summer of 2007 and again in the summer of 2008. The DTAMS were designed by William Bush and colleagues at the University of Lousville Center for Research in Mathematics and Science Teacher Development for use in measring growth in teachers' content knowledge over time. In this case, the intent was to measure growth in mathematical content knowledge among teachers who participated in MGM. DTAMS tests have been written to cover four mathematical content areas (Number/Computation, Geometry/Measurement, Probability/Statistics, and Algebraic Ideas), but MGM teachers only completed the components covering Geometry/Measurement and Algebraic Ideas. Figures 3 and 4 provide boxplots representing the pretest and posttest scores of all MGM participants in the two content areas. The scores of the four subjects of this case study fall in the range indicated by the dotted lines. The performance of the teachers in the case study was representative of the larger MGM group.

Features of Inquiry. In the 2007 Teacher Reflection given at the end of the two-week institute, teachers were asked in an open response question to identify what they considered to be the essential features of inquiry in the classroom. The following five

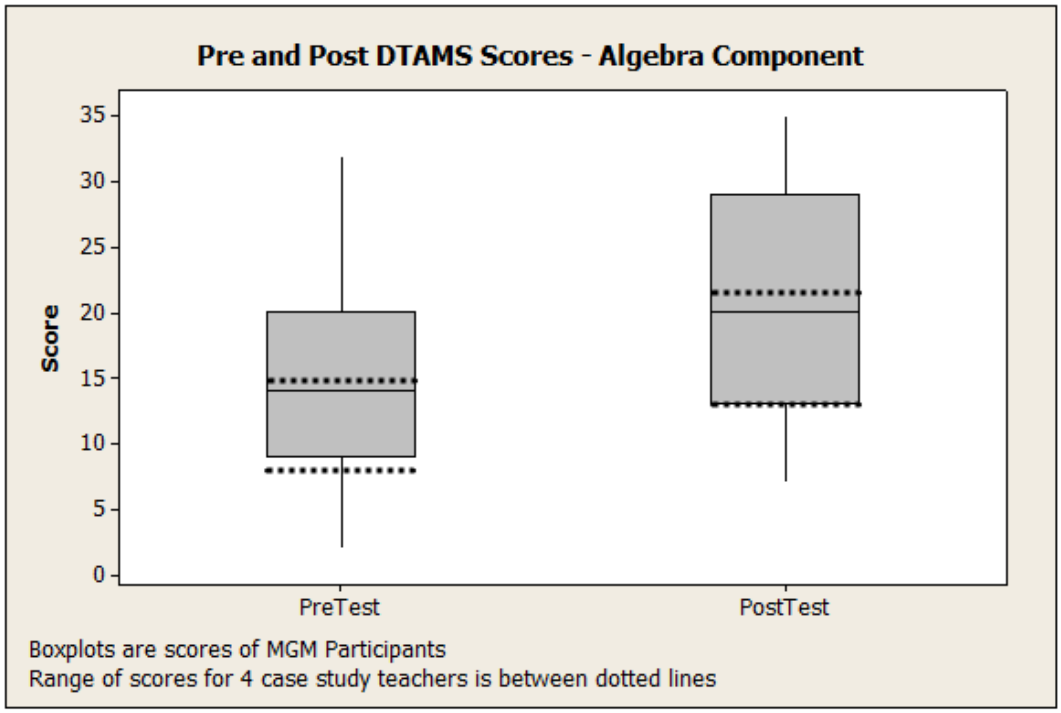


Figure 3. Pre and Post DTAMS Scores - Algebra Component

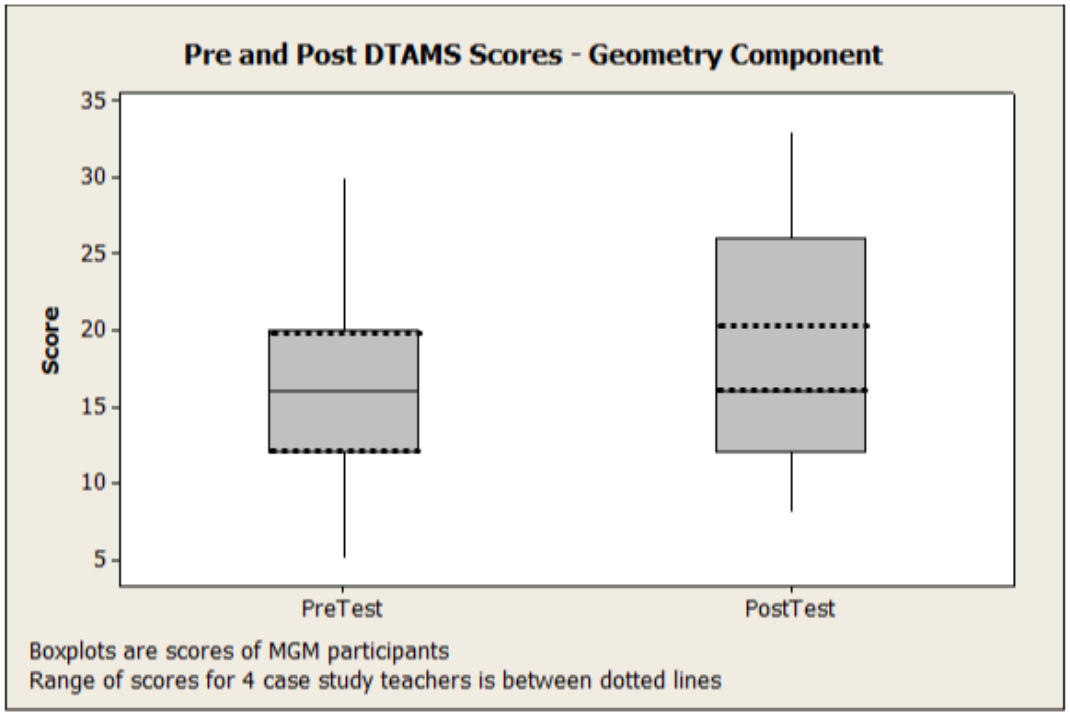


Figure 4. Pre and Post DTAMS Scores - Geometry Component

themes were identified from the analysis of the twenty-four responses: student centeredness, active/engaging, reaching all levels of students, group work, and making connections.

The teachers had spent a considerable amount of time over the previous two weeks working in groups and making sense of engaging problems while deepening their mathematical understanding, so their interpretations of inquiry were consistent with their experiences. In addition, the teachers noted that inquiry could "reach all levels of students." They had experienced this themselves as they worked at the MGM summer institute with colleagues of varied mathematical backgrounds and abilities.

Action Plans. While at the summer institute, teachers were required to write an action plan describing specific goals for incorporating new knowledge from the institute into instruction during the 2007-2008 school year. The action plans addressed three separate goals: implementing inquiry-based instruction, introducing new content (in both algebra and geometry), and either incorporating technology or focusing on standards in the classroom. Only the teachers' inquiry goals were examined in this study. The teachers submitted mid-year and end-of-year progress reports on their action plans in January and June of 2008. In their mid-year reports, nine of the twenty-four MGM teachers indicated that their teaching had undergone fundamental changes over the previous semester. The most common inquiry goals were to implement a certain number of lessons incorporating inquiry over a set period of time whether within a single unit or over a month, semester, or year. The goals of the four teachers examined in this case study will be discussed within their individual portraits.

Summary

In this section, background information was provided on the MGM program to highlight the experiences that the participant teachers were exposed to leading up to the time of this study. All four of the teachers had extensive exposure to mathematical inquiry during the 2007 MGM summer institute and had voiced some level of commitment to implement inquiry during the school year. In the next section, portraits of each of the four case study teachers will be presented.

The Teachers and Their Schools

Contextual information about the four teachers in the case study will aid in understanding the results as they are presented. The information presented in the following sections was gathered from the teachers' introductory interviews and from classroom observation. A summary of the teachers' school setting, experience, and curriculum is provided in Table 2.

Table 2. Participant Teachers

	Adelaide Traditional Text	Brisbane Reform Text
Experienced Teacher	Ms. Gilbert	Ms. Fowler
Novice Teacher	Ms. Baker	Ms. McClure

Adelaide Elementary School

Adelaide Elementary School was built in the 1950s and serves both the children of Adelaide (population 2,000) and those in the surrounding rural area that extends as far

away as thirty miles. At the time of the study, approximately 350 students attended the K-5 school. The rural experience of many of the students was exemplified by one child's choice of "What is your favorite type of combine?" as the topic for a project where he had to collect data from the other students and then produce a series of graphs.

The school adjoined the local high school, junior high, and public library. In fact, the junior high was literally down the hall from the three fifth grade classrooms. Despite being housed so close to each other, the junior high teachers had never discussed mathematics with the elementary school teachers prior to participating in MGM.

A more familial atmosphere was present at this school than at either of the schools in Brisbane. The fifth grade teachers continued to follow the development of former students. Old students in the adjoining high school or middle school would sometimes pop in for a moment , whether to say "hello" or to assist in an after school activity. Fifth graders from the other classrooms would stop by to ask questions for their teachers. Other teachers would routinely come in to ask questions or make a brief announcement. Even the janitor, a former engineer, was seen leaving class one day after giving a guest presentation on NASA.

In part because of the atmosphere in Adelaide, interruptions were not uncommon in either Baker or Gilbert's classroom. During one interview when an alarm bell was ringing outside the school, Gilbert laughed and indicated that her MGM mathematics coach had noticed the same thing about interruptions. "Whenever something like that happens, Dr. Carr just shakes her head," she said.

Ms. Baker

Background. In her fifth year of teaching at the elementary school in Adelaide, Baker was primarily trained as a science teacher and, therefore, taught science to all three fifth grade classes at the elementary school. Baker was completing her Master's degree in teaching technology during the time of this study. As part of the program, which was geared at integrating technology in all subjects of education, she took courses online with other teachers of grades four through seven. In her second interview, she mentioned that some of the discussions and activities arising from her master's courses gave her ideas for use in her mathematics class.

Prior to her participation in MGM, Baker considered herself to be very capable of teaching mathematics; however, MGM made her realize how much more she could be doing in her classroom. "I used to be pretty confident; and now, I'm like 'Oh, wow!'" She embraced standards-based teaching and used her two fellow fifth grade teachers who were also MGM participants as support while making changes.

In her twenties and very outgoing, Baker had an easy rapport with her seventeen students that extended beyond academics. After attending an out of town conference, she brought them back a stuffed bear dressed like a carpenter and named him D.J. Baker was concerned that the students wouldn't like him because they were too old for stuffed animals. Instead, the children lavished him with attention, took turns bringing him home and began producing stories and even a few videos of D.J.'s adventures outside of school.

Ms. Baker's Classroom. Baker referred to her classroom as "organized chaos," but it was a state that seemed to work for her and for her students. The children were typically

engaged in her lessons and willing both to answer her questions and to ask questions of their own. Ms. Baker only taught mathematics to her own class of seventeen students. On most days, her mathematics class ran from 1:35 to 2:00 before breaking for half an hour spent in classes such as music or library (taught by teachers outside of the grade level) and fifteen minutes of recess. The second portion of her mathematics classes lasted from roughly 2:50 to 3:25, although it was not unusual for her to still be wrapping up a lesson right before the final bell rang at 3:30.

Baker was the only teacher observed using computers in her mathematics classroom although the other teachers did have computers that they used for other subjects. The relatively new computers were crammed onto a series of tables at the back of her classroom between musical instruments and miscellaneous papers. During three separate observations (modeling the properties of triangles, constructing graphical displays, and exploring probability), students were observed using the computers as part of mathematics class. During the lessons on modeling properties of triangles and exploring probability, students from the other fifth grade classrooms came to Baker's classroom for the lesson.

Influence of Summer Institute. Ms. Baker left the summer institute determined to change how mathematics was taught at her school. In her initial interview, she stated that she felt the need to "really [motivate] everybody that math is important." She added:

> We needed to change direction. Reading is important, yes, but so is math because I felt we were just so bombarded with reading. I felt like I have more to say. I have more people listening. I felt we could convince everybody that we needed to change: change the curriculum, change the way we were teaching math and spend more time. We were really motivated.

She was initially surprised that her fellow fifth grade teachers at Adelaide felt as strongly as she did about the need to make changes in their mathematics classes.

Early View of Inquiry. In a written reflection on inquiry at the end of the summer institute, Baker felt that inquiry's most essential feature was what she perceived as its ability to help her reach students that she hadn't been able to reach in the past. She also noted how discovery played an important role in classroom inquiry. Baker wrote that the most important outcome of inquiry-based learning was that, "students will question and ask 'why' and be able to discover things on their own through inquiry-based lessons."

Even after her experience at the MGM institute, Baker did not yet possess a definitive definition of mathematical inquiry (nor did her fellow teachers in the case study). As she commented in her first interview,

> I think I'm still a little unsure what true inquiry is. I gather that seems to be a consensus for everybody. I've yet to find a website that says, "This is what inquiry is." You know, I think it might be a little bit different for each subject and each grade level.

Action Plan. Baker aimed to provide students with opportunities to engage in inquiry twice in every chapter of her mathematics text. During those times, she planned to provide her students with opportunities to make discoveries under her guidance. Baker reported having to scale back her plans due to the time commitment required for completing her master's degree. However, she also acknowledged in her mid-year report, "I have been more aware on a daily basis and find myself including more inquiry whenever I can." Therefore, while she had fewer lessons that were entirely inquiry based, smaller moments of inquiry were incorporated regularly.

As part of her mid-year report Baker was able to list several changes in her teaching practice that were inspired by her experiences at the summer institute.

> My overall teaching style has changed since experiencing our MGM summer conference. I ask the students a lot more questions such as "why" and "how" and engage them on discovering concepts through manipulatives. I used to just lecture and then have students complete practice problems. I truly understand now that it is quality and not quantity that is important. I also have incorporated the internet and other resources more often.

Ms. Gilbert

Background. Gilbert was the most experienced of the MGM teachers in Adelaide. She was in her fourteenth year of teaching at the time of this study and had a master's degree in curriculum (with a focus on incorporating arts into the curriculum). She taught social studies to all three fifth grade classes in addition to teaching reading, spelling, and mathematics to her own class. Beyond her duties in the classroom, Gilbert served as a union representative for the teachers, a job which occasionally took up her afternoon prep time and, more frequently, her evenings. In her classroom, she also hosted students enrolled in the weekly after school program.

Based on after-class discussions, Gilbert seemed to be the least confident in her ability to use inquiry in the mathematics classroom. In contrast, she was the most creative in trying to develop new lessons that she believed incorporated inquiry. These lessons were routinely shared with Baker and the other fifth grade teacher. Gilbert did not appear entrenched after her years of experience but was, instead, eager to adapt her teaching.

Classroom. Gilbert taught her fourteen students mathematics from 1:25 -2:00 and from 2:50-3:25, the same times that Baker held her mathematics class. While her classroom environment was generally calmer than Baker's, Gilbert often had mathematics lessons that were not highly structured and which lent themselves to a certain amount of unpredictability in the classroom.

Gilbert admitted to not being particularly comfortable with using computers in her classroom. Luckily, she was able to rely on her fellow teachers for support on the few occasions when her students did need to use a computer to support a mathematics lesson. At such times, Gilbert would co-teach the technology lesson or send her students to Baker for the computer lesson, while Gilbert taught a related lesson to the other teacher's students in her own classroom.

Influence of Summer Institute. When responding to a survey given at the end of the summer institute, Gilbert both discussed how she believed she had learned to persist rather than give up on mathematics problems or topics that were difficult for her. She wrote, "I learned to keep on trying and not give up if it 'looks' too hard. I would often just check out; now I know I can work towards the goal even though I may need help getting there."

Early View of Inquiry. When writing about her perception of the key features of inquiry at the end of the 2007 institute, Gilbert was the only one of the four teachers to comment about what she perceived as her key role in the discovery process of inquiry. "I think that the teacher will be the most important feature in the classroom. I will need to

facilitate the lesson in a way that the students will gain understanding through discovering it on their own with little guidance."

In the same reflection at the end of the institute, Gilbert showed cautious optimism regarding the use of inquiry in her classroom:

> I feel my understanding of inquiry-based learning has gotten better, but I have not actually done it yet so I know I have more to learn through trial and error. I look forward to using it because I feel it will help students make better connections and be able to *think* deeper.

Gilbert anticipated using inquiry in her mathematics classroom but was not quite certain about exactly how she would implement it. She commented on this uncertainty again when reflecting back on her MGM experiences during her initial interview for the case study:

> I was scared when I left MGM. I was excited; but then, when I started thinking about it more, I'm like, "Ohhh. I don't even know if I understand what inquiry is." I thought, "Can I do it?" Because I knew that our book wasn't going to help me do it.

Action Plan. In her action plan, Gilbert hoped to incorporate inquiry in five lessons over the course of the year. She envisioned using the inquiry both "to introduce new concepts and to help students make connections between concepts." In her mid-year report, she reported finding that she used inquiry as a way to introduce new concepts by basing them on students' prior knowledge. She mentioned lessons on patterning with tangrams, on introducing fractions, and on planning a party (as part of problem solving). Once she began to use inquiry in her classes, she reported, "I don't feel like I do whole lessons on inquiry, but I do fit inquiry into each lesson if possible. I still do lessons, but have found myself questioning differently and having the students doing more explaining

of their knowledge in class and with partners." Much like Baker, Gilbert reported using inquiry but entire lessons were not typically dedicated to inquiry.

Bartleby Elementary School

Bartleby Elementary is a two-story building constructed in the heart of Brisbane (population 35,000) in the 1920s. When the study took place, it served approximately 300 students from kindergarten through fifth grade. The poorly lit hallways were lined with lockers and examples of student artwork. The building was decidedly older than other schools visited in this study. The school was in its first year of adoption of the *Everyday Mathematics* curriculum, which had been selected by the district the previous spring.

Bartleby prided itself on its commitment to the arts, for which it received national recognition. This commitment translated into extra work for the teachers, who ended up involved in preparing for an annual art auction and an original opera. There were times when regular classroom instruction was interrupted to prepare for these events.

Ms. McClure

Background. At the time of this study, McClure was in the midst of her second year of teaching in one of Bartleby's two fourth grade classrooms. Prior to her first year in the classroom, McClure spent a year working as an aide for the resource teacher where she spent most of her time performing reading interventions.

While all of the teachers in this study had professional commitments outside of the classroom, McClure's school commitments took her away from her classroom the most

as evidenced by the number of observations which had to be rescheduled because she was out of school. In her initial interview, she stated that she was on five different district committees including the committee to select a new social studies curriculum, another to study an alternative type of special education (of particular interest to her), and yet another to help implement a grant for Indian Education for All. McClure was beginning to realize the implications of her many involvements:

> I'm out pretty regularly it seems this year. I just have to learn to say no and not take everything. I just get so excited about so many things that I have to just remember that I've got 20 more years of this left. I don't have to do everything the first two years I'm a teacher.

McClure acknowledged that her area of specialty was reading and that mathematics was a bit more out of her comfort zone. She said that she turned away from mathematics after a poor experience with a high school teacher. She described the experience in her first interview:

> I did Algebra I, Geometry, and Algebra II and then I started trig my senior year and my math teacher and I just didn't connect. He was a great guy. He was a fabulous mathematician, but he did not understand my need to talk. There were only eight of us in there and so we could have been working in partners. I'd go in after class; and when we'd talk through it, I'd get it. But when I'd have to do the test where I'd have to sit there with my mouth closed, that completely ruined my perception of myself as a math person and I think that carried over into my teaching for the first year.

However, McClure said MGM had given her an "ego boost" and reminded her that she was able to do mathematics.

A fifth grade teacher who also attended MGM was located just down the hall from McClure's classroom. While the two teachers got along personally, they did not

communicate regularly about mathematics due to differences in teaching styles. McClure stated, "She's definitely abstract random and I've got my routines."

Classroom. McClure's twenty-three students did follow an established routine during mathematics. The first fifteen minutes of every class were dedicated to the practice of "math facts" (skills practice on either addition, subtraction, multiplication, or division). Students would then proceed through a series of steps starting with spending one minute on reading math facts and ending several minutes later with completing a timed test for mastery of facts. Afterward, folders would be collected and McClure would present her lesson. Even during investigative lessons, her students were typically at their desks and working in a comparatively orderly and quiet fashion.

However, occasional moments of liveliness were observed in class, usually before or after the mathematics lessons when McClure might tell them a joke or speak to the students in a funny voice that they loved. McClure's classroom had the most modern feel as all of the students would be seated on yoga balls behind desks which held bottles of water. Several of the girls even kept fuzzy slippers underneath their desks.

During this study, Ms. Buck, the school's resource teacher, came to McClure's mathematics class on a regular basis to work with the special education students who were included as part of the regular classroom. On days when Ms. Buck came to assist, McClure would lead the lesson and then Ms. Buck would target students during their independent work time or pull them out to work with her in a group.

Influence of Summer Institute. Much like Gilbert, McClure noted in a reflection at the end of the 2007 institute that she had seen the benefit of persistence while learning

mathematics over the course of her participation. She stated, "I do not like feeling uncomfortable [not] 'getting' things right away. I am known to just give up. This week I tried to keep going."

In her initial interview, McClure said that she left MGM with an increased awareness of mathematics in general and a belief that she could teach it successfully. McClure described her mathematics classes during the previous year, her first year of teaching, as "awful." In that same interview, she went on to say:

> I struggled significantly with our old program. [It] was not a teacher friendly program. It was a: "Here's how you do an algorithm, give the kids twenty problems." As far as the manual, it didn't give lots of hints as to how to reach the kids who weren't getting it or challenged. You know, it was basically, everybody got the same kind of math no matter where they were and it just wasn't good. I didn't like it and math was not an area I was comfortable with to begin with.

In the year before MGM, McClure had been relieved whenever she was able to avoid teaching mathematics on a particular day. However, she reported in a reflection following the summer institute that she felt more confident in her abilities as she left. She expressed how she felt more at ease with trying to emphasize conceptual understanding and reasoning in her mathematics classroom. She stated,

> I did not feel comfortable with the way I was teaching math previously. I felt like I was just giving the kids steps to complete, but they did not have anything to relate those steps to. Now I feel like my kids will be learning math concepts and reasoning rather than just computation.

Early View of Inquiry. In the same reflection at the end of the summer institute, McClure emphasized how she saw inquiry as a process where the journey was of more importance than the destination. She stated her feeling that her students' abilities to reason through problems were more important than the answers they found.

Action Plan. In her action plan, McClure planned to include inquiry once within every unit of mathematics instruction. McClure wrote in her mid-year report that she was able to meet this goal easily due to her new mathematics curriculum. She said,

> Fortunately, our district adopted EveryDay Mathematics. This has made meeting this goal attainable. Before beginning a unit, I quickly scan the lessons and try to identify which ones are already inquiry-based. Luckily, [every] unit has included some sort of inquiry experience for the children.

Brookings Elementary School

As part of the Brisbane school district, the teachers at Brookings Elementary were also engaged in their first year of teaching mathematics from the *Everyday Mathematics* curriculum. Brookings was located in a housing area which had been built comparatively recently. The school itself was constructed in the 1980s, making it considerably newer than either of the other schools in the study. It was a single-storied structure composed of a number of wings each of which contained multiple grade levels. The school housed approximately 500 students from kindergarten through fifth grade with the three fifth grade teachers clustered at the end of one wing. The carpeted hallways were wide, brightly lit, and intermittently decorated with pieces of student work.

In an informal interview that took place during a classroom observation, Fowler volunteered that she believed students at her school came from families that had "a lot less money" than families of students at Bartleby Elementary. She said, "You wouldn't think it would make a difference, but it does with respect, value of education, and parental involvement." She went on to say that she felt like some children were effectively raising themselves.

The school prided itself on celebrating the individuality of its students. In addition, the school strove to promote health and wellness through weekly prize drawings for students who had participated in the challenge of the week, such as eating fruit everyday or playing outside for fifteen minutes daily.

Ms. Fowler

Background. In her nineteenth year of teaching, Fowler had seven years of experience teaching fifth grade students. As with McClure, her students received all of their instruction from her with the exception of classes like art, P.E., library, and music. Unlike the other teachers, she did not name a particular subject as her forte. Instead, she called herself as a "jack of all trades, master of none." She went on to say,

> I would be really hard pressed to even choose a favorite to tell you the truth. I love teaching the Everyday Math. I love teaching the U.S. History, the social studies, and the different science units. I like this grade level and I like the curriculum.

Fowler mentioned repeatedly during observations how busy she was, but always made it a point to say that the observations themselves were not a disruption. Instead, she referred to assemblies, parent conferences, report cards, and chance meetings with teachers or administrators which took up her time.

Classroom. Fowler's room was the most decorated and colorful of the four observed. Nearly every available surface was covered with pictures, posters, or student work. The students' names, artistically cut out and decorated, dangled from the ceiling upon which a few posters were also hung. Lists related to various topics including grammar, mathematics, and behavior hung on walls and cabinets. One of her bulletin boards was

covered with neon cards in pockets each containing mathematical questions for the children to answer.

Fowler's fifth grade classroom had a large window overlooking a small garden area. She was particularly fond of birds and had a number of bird pictures scattered about her room, along with a bird's nest for the children to see. As part of her list of designated jobs for the week, two students had the responsibility of scattering seed outside for the birds.

In her initial interview, Fowler said that her class of twenty-five students was extremely unmotivated this year and that this was a characteristic that other teachers in the school had observed in their classes as well. She was very aware of the large number of students who were either on or probably needed to be on medication for attention deficit disorder. Her observations about her students stood in contrast to those of the other teachers who had little to say about their students with the exception that they were fairly average performers.

Although not all students were necessarily on task at any one time, Fowler's classroom typically felt very controlled. While students would routinely stand up to sharpen a pencil, go to the restroom, or blow their noses, seeing more than one student out of place was rare. Fowler's students were not necessarily more engaged in their work than students in the other three teachers' classrooms; rather, they were less disruptive to others at times when they were not engaged.

Fowler was the only teacher to overtly demonstrate teaching strategies gleaned from conferences and articles. For instance, when going over a daily warm-up

mathematics question, she would call on students to either give an answer or to call on someone else to give the answer for them. She would then have the student who answered call on two other students to check their answer before finally asking for an explanation of the answer. As another example, each of her students had clock partners (one for each hour on the clock) with whom they would pair up to work after she told them the "appointment time." In this way, she was able to make the students work in different pairs without having to do the work of regrouping them herself.

Fowler had mathematics instruction in the morning, and like the teachers in Adelaide she dealt with an interrupted schedule. On Mondays, Tuesdays, and Fridays, Fowler taught mathematics from 8:45-9:25 and from10:20-10:50. On Wednesdays, mathematics ran from 8:50-9:10, from 9:50-10:25, and again from 1:30-1:45. The final fifteen minutes on Wednesdays were typically reserved for skills practice and sometimes reallocated to different subjects. On Thursdays, she taught mathematics from 9:45-10:50. During the gap between the two morning chunks of instruction, students went to other rooms for activities such as library or gym.

Prior to participating in MGM, Fowler had tried to implement inquiry into her classroom by supplementing her mathematics instruction from the text with activities from other sources. For instance, she mentioned that she used to incorporate activities from Marilyn Burns into her classes but no longer felt the need to do so because of the new *Everyday Mathematics* curriculum.

Influence of Summer Institute. Fowler stated in her initial interview that she had felt confident in her mathematical abilities before MGM began. However, she chose to

participate because she knew her district would be starting to use a new mathematics series with additional emphasis on algebra. While at MGM, she realized that in the past she had learned mathematics by rote without real understanding of the concepts.

> I had an epiphany at math camp [the participants' nickname for MGM]. It took me a while and I couldn't figure out why I was struggling so much with the concepts and so many of the things that we did. And then it finally occurred to me that the way I had been taught math was that I had not been taught any "whys" of what it was. It had all been, here's the formula, do it, apply it to this situation….Some of the things I even teach the kids in fifth grade now and I look at it and go, "Wow! You know that's really cool! I didn't know it was like that."

Early View of Inquiry. At the end of the institute, Fowler completed a reflection on what she believed to be the most critical features of inquiry. Fowler believed that the engagement of her students would be the most critical. However, Fowler also noted how discovery played an important role in classroom inquiry. She said she felt that student discovery was a goal rather than an expectation. She stated, "A nice bonus of inquiry would be to have students discover concepts…I'd like them *increasing*, adding on to what they know as they keep trying to solve what they don't know."

Action Plan. In her action plan, Fowler planned to include inquiry once per unit over the course of the school year. As part of that she aimed to "provide lessons that would offer the opportunity for kids to ask questions, investigate, observe, and reflect on their experiences." Ms. Fowler found that her new curriculum, *Everyday Mathematics*, provided her students with more opportunities to engage in inquiry than she had predicted. She said, "I've found our new math curriculum, Everyday Math, to be extremely rich in inquiry and not needing to be supplemented by other resources. My

kids are constantly provided with inquiry opportunities." Due to the opportunities provided by the new classroom text, Ms. Fowler felt she was able to meet her original goal without have to develop lessons of her own.

Summary

The four teachers in this study possessed different levels of experience and different areas of expertise; however, based on researcher observations and conversations, they were all committed teachers who cared about their students. In this section, background information for each of the teachers and their MGM experiences leading up to the time of this study was provided. Baker and Gilbert, both from Adelaide, worked with a traditional mathematics curriculum. McClure and Baker of Brisbane had just begun using a reform-based text. They all felt they had included inquiry lessons in their mathematics classrooms during the fall of 2007 (prior to primary data collection for this study).

Inquiry in the Classroom

This section addresses how the participant teachers operationalized inquiry-based instruction in their classrooms. Each teacher was observed in the mathematics classroom fourteen times over the course of Spring 2008. After a brief description of how the observational data was collected and analyzed, individual findings brought to light through the observations and the modified RTOP will be presented for each teacher. These will be followed by several brief comparisons among the teachers. Afterward,

factors which the teachers identified as influencing their use of mathematical inquiry in their classrooms will be detailed in a separate section.

Origination and Analysis of Observational Data

Collection of Observational Data. Field notes were taken during each observation. At the end of each observation, the teacher was asked whether she thought inquiry had been present in the classroom during that lesson and the teacher's response was documented by the researcher at the end of the day's fieldnotes.

The researcher also completed a modified portion of the Reform Teaching Observation Protocol (Piburn, Sawada, Falconer, Turley, Benford, & Bloom, 2000) after each observation. The protocol, referred to hereafter as the RTOPmod consisted of a series of twelve items scored using a Likert scale to rate aspects of the lesson design (e.g. "The lesson was designed to engage students as members of a learning community") and of its enactment (e.g. The focus and direction of the lesson was often determined by ideas originating with students.).

As part of the observation protocol, the approximate percentage of instructional time in every class period was broken down as to whether the students were working individually, whether they were working in small groups, or whether the class was meeting as a whole. Appendix D contains specific information on how instructional time was allocated in each lesson and provides means and medians as an overview of how each teacher utilized mathematics instructional time during the observed lessons.

The time spent as a whole class requires extra clarification as this time was used in two distinct ways. In the first case, the classroom was teacher centered wherein the

teacher was primarily presenting information to the students with limited input from the students. In the second, the classroom was much more student centered. On days when the latter occurred, the notation "Interactive Discussion" was typically made under the percentages to indicate that the students (and their teacher) were engaged in a conversation about the material.

Uncertainty about the overall reliability of the observation protocol was discussed in Chapter 3; however, the tool was still useful as a means of organizing the observational data. This section opens with a description of results viewed initially through the observation protocol.

Coding of the Fieldnotes. After the end of data collection, the fieldnotes were coded using codes which emerged from the 'Is It Inquiry?" Interview, which will be described in more detail later along with its coding process. The interview gave a detailed portrait of each teacher's view of mathematical inquiry, and the resulting codes from that interview helped to focus the analysis of the observations. This additional focus was needed as the fieldnotes contained information on over fifty classroom lessons, many of which had little to do with inquiry itself.

Analysis and Findings from the RTOPmod. The RTOPmod observation protocol was used to identify the highest and lowest scoring observations as well as an observation that scored in the mid-range for that teacher. Appendix D contains more detail on particular scores. These observations were identified by taking an average of the first five items on the RTOPmod as they were the items identified by Henry, Murray, and Phillips (2007) as pertaining to inquiry in a factor analysis of the RTOP.

The following sections describe the teachers' lessons on the days identified from the RTOPmod as representing a high, low, or mid-range score for that teacher. The results are presented by teacher, beginning with Baker and Gilbert who shared some common lessons and ending with Fowler who had a particularly high scoring lesson that is presented in more detail.

Baker's Lowest Scoring Lesson. On the day of Baker's lowest scoring lesson, the class focused on two distinct tasks. During the first fifteen minutes of class, the students were given time to finish up a park design project. Baker had previously associated the project with mathematical inquiry; but on this day students were just placing the finishing touches on their projects (such as coloring in vibrant colors or revising a one-paragraph description).

The rest of class was spent reviewing for the upcoming criterion referenced test. Baker said, "No [there was no inquiry], we just reviewed all day." The students went over released items from previous tests using the overhead projector. Students used small white boards to work on the problems either individually or in small groups before whole class discussion of each problem. As part of the process, students were asked to justify their answers (such as why they placed a decimal where they did) and share their different approaches; however, Baker felt students were merely revisiting old information and not looking at it in a new perspective.

Baker's Mid-Range Scoring Lesson. For the first 15 minutes of Baker's mathematics class, the students worked on two "problems of the day." The students worked on them independently but individual students volunteered to share their thinking on each of them

during whole class discussion. The students presented two different approaches for solving a question about how much a batter's average had increased from one season to the next.

The bulk of Baker's mid-range lesson was over perimeter and area. When asked about whether inquiry was present in the lesson, Baker commented, "Well, to some extent." Her students had done some measuring, and because they were actually active, she thought there was some inquiry but she did not feel the entire lesson was inquiry based. Her goal was for the students to calculate the perimeter of different figures using measuring tapes and without the use of a formula. In the past, perimeter had been presented to the students as a formula to memorize and this year she was not presenting them with formulas but letting them develop their own strategies. The students each used their tapes to measure a series of shapes and confirmed their answers with others around them. Her students had done some measuring; and because they were actually active and not blindly plugging into a formula, she thought there was some inquiry but she did not feel the entire lesson was inquiry based.

Baker's Highest Scoring Lesson. Baker's highest scoring lesson occurred near the end of the semester on a day when all of the fifth grade students were supposed to rotate from classroom to classroom engaging in different probability activities. In her classroom, Baker had her computers set up each with one of six probability games or applets that she had found online. The students were to work in pairs.

After twenty minutes, it was clear that the students were not going to have time for all six games. She, therefore, modified the activity to contain just the two computer

games that she thought were the most worthwhile. In the first one, students could randomly draw one item from Santa's sack and then return it before drawing another item. The goal was to determine how many times items had to be drawn from the sack in order to know all of the presents that were in the sack.

In the second, students were given two fish tanks with red and yellow fish and told to place fish from the second tank into the first in order to have a certain percentage of red fish in the first tank. Fish could not moved from the first tank to the second.

Throughout the lesson, it was apparent that Baker was engaging in inquiry along with her students. She realized early on that the games required more thought than had first appeared. Of her lesson on that day, Baker said, "I do [believe there was inquiry] because honestly, they were helping us as much as we were helping them and they made a connection to science which I didn't even realize."

The students were focused on figuring out the key to the games. This was especially true after the number of games had been reduced to two. While some classrooms would have been tense when the teacher did not have the answer to present, both the students and Baker remained positive throughout. By the end of the class, a few students had figured out the importance of using percentages in their predictions of the items in Santa's bag. Others had made the important realization in the fish game that the statement, "Three fourths of the fish were red" did not mean that there was a ratio of three red fish to four yellow fish. At the end of the class, the students were not done with the activity. They still had more thinking to do; however, Baker, who had reached

her own conclusions, resisted the temptation to present the students with the answers and instead promised them more time to work the following day.

Gilbert's Lowest Scoring Lesson. Gilbert centered her lesson about the interpretation of bar graphs, saying "It was range, means, medians, and mode. I didn't know how to do inquiry with that. I just gave it to them and let them go with it." Based on observation, it was evident that she had taught a traditional teacher centered lesson. She placed her book on a document camera in order to display different graphs to her students and proceeded to ask them the accompanying questions, which were short answer with little to no justification.

Gilbert's Mid-Range Scoring Lesson. Gilbert's lesson which scored mid-range on the RTOP was over area. The day before, her students had learned about perimeter which she reviewed before beginning with the area of rectangles. Instead of presenting a formula to her students, she asked her students what area meant to them. The students arrived at, "the area inside of a shape," and one student drew an irregular polygon on the board and pointed to its interior. Students were given grids with rectangles drawn on them and asked to calculate their areas without being told how to do so. Afterward, students spoke of counting squares, counting edges but subtracting one for each corner, and the more traditional multiplication of the length by the height. Of her lesson, Gilbert said, "There was maybe a little [inquiry] because I didn't give them the formula for area. Other than that, I'm not really sure how you would do inquiry with area or perimeter."

Gilbert's Highest Scoring Lesson. Gilbert's highest scoring lesson was on the same day as Baker's high scoring lesson and involved calculating probabilities of winning while playing the game Rock, Paper, Scissors in pairs. The goal was for students to be able to make discoveries related to the Law of Large Numbers (although that term as well as the terms experimental probability and theoretical probability were intentionally never used with the students). The students needed very explicit instructions on how to set up their tally sheet for recording whether they won, lost, or tied but otherwise understood their instructions.

After playing eighteen rounds, the students continued to work together to draw their conclusions. The difficulty arose when the students had finished playing. Results varied between groups and no clear pattern arose from the theoretical probabilities. Gilbert had the students play eighteen more rounds. There was still no clear pattern emerging although the students were openly sharing ideas. After pooling all of the results, the probability of winning appeared to be approximately one half instead of one third. After engaging in some inquiry of her own, Gilbert with insight from Dr. Carr believed that the students were not randomly selecting whether to throw the rock, paper, or scissors. Gilbert realized she needed to use spinners to make the students' decisions more random. From there, the students were able to proceed through the activity with greater success although Gilbert extended the lesson to the following day in order for them to have more time to develop their conclusions.

McClure's Lowest Scoring Lesson. McClure's lowest-scoring lesson was over percents and using them to solve word problems. It was taken directly from the fourth

grade *Everyday Mathematics* text. Her comment on the lesson was, "I have honestly no idea today. The lesson went so far off track when I didn't have them use calculators. I don't know what today was." On this day, the children's work focused on using hundred grids to represent percents and then using these representations to determine what a certain percentage of a given number would be. Students had just learned about the computational connections between decimals and fractions. They began the lesson by discussing how to convert fractions such as 75/100 into a percent form. From there, the lesson jumped into asking the students to find sale prices or, in some cases, the discounted amount of particular items. The leap was too great for most students who drew and shaded the hundreds grid models but did not understand how to use them to find the quantities that were required.

Furthermore, the first example included finding the savings on an item with 10% discount. In demonstrating the solution, the workbook displayed $\frac{1}{10} \times$ the original price which led many students to the false conclusion that they could solve similar problems by converting the percent to a fraction by writing it as $\frac{1}{percent}$. During class, McClure commented, "This is hard. The kids are making jumps that they're not ready for and I'm not ready for either." Towards the end of the hour, she decided that the text had intended for her students to simply hit the percent button on the calculator in order to do the computations even though they would not have really understood what they were doing. The difficulty of this lesson, which was well above their previous lesson, made it inaccessible for the majority of the students.

McClure's Mid-Range Scoring Lesson. In this activity, students used pattern blocks and determined what fraction of one they represented. It is included in Appendix G as the Parts of a Whole activity. The use of hexagons as a basis for one whole added an element of difficulty. In addition, the "whole" changed from problem to problem.

The students each had a set of pattern blocks at their desks and worked independently through the problems (with the exception of the last problem where students had to share their blocks in order to have enough pieces to work with). After a few minutes, McClure would stand behind the overhead, ask a student what he or she found, and then place the appropriate pieces to demonstrate the answer to the students. There was very little discussion about the answers and McClure's questions were of the nature, "What is one whole?" and "What did you get?"

When asked about inquiry in the lesson, McClure stated, "I didn't feel like it was inquiry because the students were just building on their earlier knowledge." The lesson was rated higher than McClure indicated by her answer as students were seen quietly making discoveries about equivalent fractions over the course of the observation.

McClure's Highest Scoring Lesson. McClure's highest scoring lesson was one on finding the volumes of rectangular prisms. Students, working independently, used centimeter grid paper to construct nets of rectangular prisms with varying dimension. They would then use the net to make a hollow prism which they filled with centimeter cubes. They would record the number of cubes that it took to fill the rectangular prism on the bottom of the net. After the students had repeated this process with multiple prisms, McClure began asking them what they noticed. Students sat quietly. They were

thinking but were unsure how to progress. Finally, McClure asked students to tell her the dimensions of their prisms and their corresponding volumes. She recorded them on the board and asked if anyone saw a pattern. One student did and told her if she multiplied the dimensions together, she would get the volume. McClure wrote the answer on the board, the students wrote down the answer, and then the students began to prepare for recess. Of that lesson, she said, "Yeah, I think it was [inquiry] because by the end all but one of them figured out how to find the volume of the cube and I didn't tell them how."

Fowler's Lowest Scoring Lesson. Fowler's lesson on addition and subtraction of integers did not include inquiry. This was because the students were in the first phase of a multi-day lesson (the only such lesson not taken from the *Everyday Mathematics* text) and she was expecting mathematical inquiry to occur in the next day or two after they had sufficient background. Regarding inquiry, she said, "Not exactly. Well, we started. What I had them write in their journals, we'll work on more tomorrow. I want them to get together with a partner and start developing the rules for adding and subtracting negative numbers." She had spent the day providing students with context in the form of a town vertically oriented on a cliff in order to provide them with a context for thinking about negative numbers. Students had been presented with the model and shown simple examples. They would be expected to apply that knowledge in the following days.

Fowler's Mid-Range Scoring Lesson. Fowler, whose lesson mixed number addition and subtraction, said the level of inquiry on that particular day was "About like the day before," when she had said, "There was maybe the teeny tiniest little bit when they were working together to form their strategies but not much." The day's lesson began with a

challenge to the students to see if anyone could figure out how to use their calculators to enter a mixed number. Cory was the first to learn the method after reading the instructions on the calculator case. He received praise for actually reading the directions and then presented the steps to the class on the document camera.

Afterward, students were given instructions for a game they would be playing with the aid of their calculators. The game board consisted of addition and subtraction inequalities with no numbers (e.g. ___ + ___ > ____). Students took turns drawing cards and immediately placing them in a blank with the goal of eventually making a true inequality. The students played in pairs and had difficulty getting started since they had no strategies for placing their cards. About half of the time they were playing was spent in chit-chat but all but a couple of students made it through the game at least once. Afterward, Fowler asked students to share their strategies. Students shared comments such as "If I got a higher number, I'd look and see if it was supposed to be higher than a number. I'd just put it there because there's no way I couldn't get it." Fowler would then provide a few examples for the students using numbers so that the others would have a better chance of understanding the strategy.

Fowler's Highest Scoring Lesson. Fowler's lesson from May 8th was her highest rated lesson on the RTOPmod protocol. It is presented here not because it was a perfect lesson but rather to provide one example of classroom interaction observed in this study in the context of a lesson that scored highly on the protocol. This lesson was not remarkable for the new discoveries that the students made on their own. Instead, it

scored highly because the students actively engaged in exploration as members of a learning community by discussing and thinking critically about one another's ideas.

Prior to this day, the students had completed exploratory lessons on how to find the area of different types of triangles. As usual in Fowler's classroom, the students spent the first half hour of the class completing their Math Boxes and discussing the answers that they found. From there, the lesson turned to what Fowler had envisioned to be a brief activity where the students wrote their own definitions for the "base" and "height" of a triangle. While the children had been computing the area of different triangles for a number of days, they had done this by building rectangles that enclosed the triangles and dividing the area of the resulting rectangle by two. Students had not been thinking in terms of base and height.

Although this was intended to be a brief activity, the resulting discussion lasted half an hour. During that time, the students spent a short time thinking independently but spent the bulk of the time sharing their individual ideas with the whole class. After class that day, Ms Fowler mentioned that she had thought about breaking her students into small groups but did not think that many of the students were ready for that.

What one might have expected to be a particularly dry topic turned out to engage the class more than any other lesson that was observed over the course of the semester. Field notes on that day included the comment "They really are excited about this!" Students listened raptly to one another instead of doodling on their papers or staring out the windows. In addition, the classroom discussion was not dominated by one or two

high achievers; instead of those couple of students doing the work of discovery for their peers, the students were building their knowledge as a class.

After the students opened their books to look at sample pictures of triangles, Ms. Fowler gave them a few minutes to write their own definitions for base and height while sitting at their desks. A number of students' pages remained blank. One student, Mark, had written, "The base goes horizontal. The height goes vertical."

After giving the students a few minutes to think, Fowler asked the class as a whole, "Can I look at any one of those figures [in the book] and make your definition work?" Mark murmured, "No," to himself. The students then began to share their ideas with the class. Their discussion follows.

Ava: The base is the bottom of the shape. The height is how tall it is.

Luke: The base is always outside the figure.

Brad: The bottom.

The students continued proffering ideas but did not accept any as a group. Then Lana observed, "The base and the height always come together at a right angle." She had to repeat it three times to be clearly heard.

Fowler: Ooh. That's nice, but what's the base?

Lana said: How long it is.

"Keep it simple now," said Fowler. She drew a non-right triangle on the board (see Figure 5a) with sides that were neither horizontal nor vertical. She drew an arrow toward one side and asked, "What would you call this?" Students called out a variety of

words including equilateral, angle, bottom, and horizontal. "Keep going. You're using simple words and that's what I want," she said. Carter finally identified it as a side.

Mark: So the base could be the height and the height could be the base?

Kent: The height goes up.

Mark: Not in that picture. It goes across.

Kent (insistent): But it's still going up

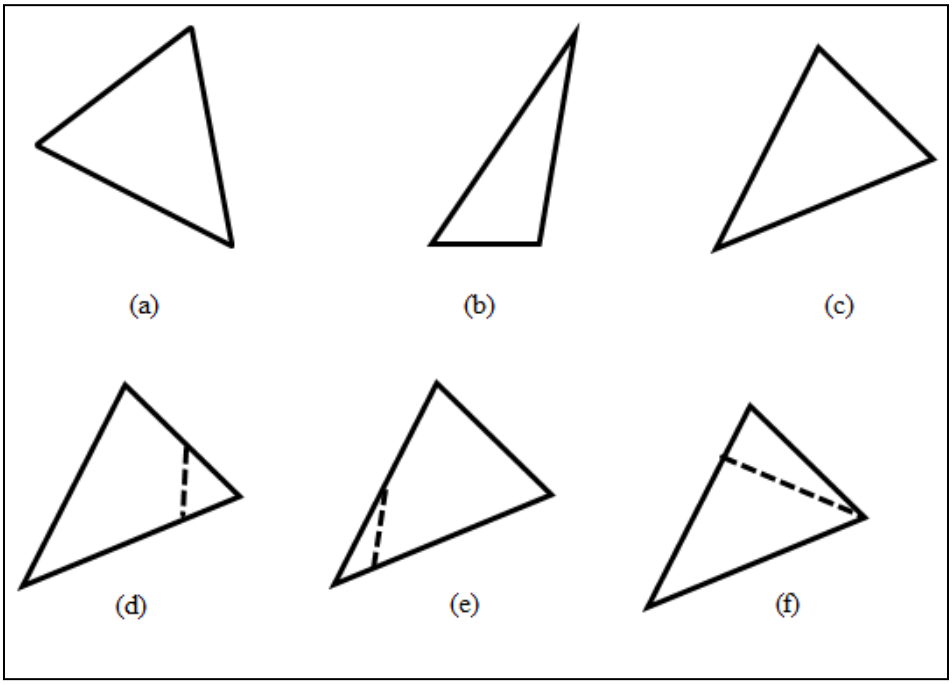


Figure 5. Triangles from Discussion

At this point, Fowler sat down to listen but asked them to continue.

Lana: The base is the longer one.

Mark: Not necessarily. In this picture (Figure 5b) the height is longer than the base."

Debate continued for a bit longer until the students were literally on the edge of their seats. Emotions were running a bit high.

Kent said, “This is crazy!” and Mark added, “This is tight.”

Lana and Mark went to the board to draw the picture they had been referring to. Meanwhile, Page joined the conversation.

Page: Most of the time the dotted line is from a point or an angle.

Kent: The height and base do make a right angle.

Trina: That’s what the dotted line does in all of these! It makes them meet at a right angle.

Two of Trina’s classmates clustered around her to better see what she was talking about. Mark and Lana asked permission to use the document camera, but they started whispering to each other, unsure of what to say to the class. Speaking of herself and the couple of students huddled about her desk, Trina said, “Ms. Fowler! We figured it out!” She moved up to join Lana and Mark at the document camera.

After a minute of whispering, Fowler encouraged the three students to share their thoughts with the class. At this point discussion had been going on for about fifteen minutes. Mark placed his text on the document camera, and pointed to the triangle in the bottom left corner. He said, “If you just add the dotted lines (Figure 5a), the base is still more than the height.” Either he was confused or he changed his argument after talking with Lana.

Lana (disagreeing): The height is always going to be shorter than the base.

Fowler: How do I know where I’m getting the height?

Trina: The base will be the longest side and the height will meet at a right angle.

A new participant in the discussion, Selena, brought up a possible problem with Tina's interpretation, "But that won't work with an equilateral triangle. All the sides are the same." Fowler nodded and said in an impressed tone, "Ooh. Someone always throws a monkey wrench in things." Lana responded by saying, "I think that in the case of an equilateral triangle, you'd cut it in half using the rectangle method and that would be the height."

At this point, Fowler returned to the front of the room and asked the students at the document camera to return to their seats. From this point, she used questioning to steer them toward the conclusions for the day. She asked, "Does anyone else have something to share?" before continuing with, "If I'm going to draw a line for a height where should I start?" On the board, she then drew a triangle as in Figure 5(c). She then drew a few different line segments connecting one side of the triangle to another side as in Figures 5 (c) and (d). In each case, several students insisted that what she was doing was incorrect.

Bryce raised his hand and was asked to sketch in the height for that particular triangle. He used the disclaimer, "I'm probably wrong," but proceeded to correctly sketch a height from one base to the opposite vertex as in Figure 5(e). Fowler asked him to place the marker where he finished (on the vertex). She then asked the students if they knew the name for where the two sides met. Different students began excitedly making suggestions: intersect, line segment, intersecting, ray. Finally, Fowler told them it was called a vertex and had Bryce write the word on the board.

Fowler: Now my height is going to go from where to where?

Sam: From the vertex to the other side

Fowler: What's another word for "other"?...Black, white…

Tim: Opposite.

Fowler (affirming): Opposite. Go ahead and fix your definitions. (Pause while she writes.) The height is the distance from…

Trina: The vertex.

Fowler (agreeing): To…

Lana: The opposite base.

Fowler then drew another triangle on the board and drew a non-perpendicular segment from a vertex to the opposite side. "What else do we need?" she asked.

Ava: A right angle

Fowler: Because that's actually going to give us the shortest distance across. Now, Mark was using rectangles. Was that okay?

Luke (pointing at an obtuse triangle): Yes, especially if you have something like this.

From there, the class discussed the word 'altitude' for a minute and then spent a couple of minutes working individually to identify the base and height of a number of triangles in their text. As the lesson drew to a close, students checked their answers by making sure that the two dimensions met at a right angle.

After class, Fowler affirmed the presence of mathematical inquiry in the lesson as she said,

> Yes [there was inquiry], with all of their discussion. I'd like to have this more often but you never know when it's going to click with them so they will talk. The lesson went in a different direction than I had planned and we didn't get through the whole thing, but I felt it was worth it.

Teachers' Self Awareness of Inquiry Implementation.

In order to gauge the teachers' awareness of how and when inquiry appeared in their classrooms, the teachers' responses as to whether or not inquiry occurred in their classroom on that day were then compared with the degree of inquiry present based on the protocol. This comparison was done on the low, mid, and high scoring lessons for each teacher. With the possible exception of McClure, this analysis indicated that the teachers possessed a strong self awareness of the degree of inquiry activity in their classrooms as evidenced by the correspondence between the observational scores and the teachers' replies.

Low Scoring Observations. In their snapshot interviews, the teachers all indicated that their low scoring lessons had not included inquiry. However, inquiry was absent in these lessons for different reasons. Gilbert had taught a traditional teacher centered lesson. Fowler had plans of incorporating inquiry into her lesson on integers but did not reach the point in her lesson where she envisioned it. Baker was in the midst of a review, and McClure's students had difficulty engaging in the day's lesson which connected poorly to the lesson of the day before.

Mid-Range Scoring Observations. Fowler, Gilbert, and Baker indicated that inquiry was present but not to any great extent in their mid-scoring lessons. Instead, they observed brief moments of mathematical inquiry. McClure stood in contrast to the other three teachers with her thoughts about the fraction lesson where students were exploring

how the same pieces represented different fractional parts of different wholes. She did not feel that there was any inquiry in the lesson.

High Scoring Lessons. On their highest scoring days, each of the teachers stated that mathematical inquiry was present in her classroom. In none of the highest scoring observations did the lesson go exactly as planned. Fowler made that clear in her description of the lesson on triangle base and height. Baker asked her students to draw conclusions from probability games that she had not yet studied in depth herself. She and her students thought through the games and made discoveries about strategies together. Similarly, Gilbert's students ran into difficulties when their experimental probabilities in Rock, Paper, Scissors did not align with the theoretical probabilities that they had predicted. According to the curriculum in McClure's class, the students were not expected to discover the formula for volume until the following day, but the class pushed through and reached their conclusions from this lesson instead of from a later one.

Different Approaches to Whole Class Structure

McClure's classroom looked the most different from the others in terms of classroom structure. Her students spent the most time working individually, and the percentage of time spent as a whole class was lower than for any of the other three teachers. Furthermore, time spent as a whole class looked fundamentally different in McClure's classroom. There was very little discussion taking place. Instead, McClure would ask a question, a student would give a short answer in response, McClure would write it down and the class would move on. In the case of Fowler, Gilbert, and Baker, the time spent as a whole class was more student centered, with students sharing ideas

more than reporting answers.

Different Approaches to Small Group Structure

Based on the fourteen observations of each teacher, the median proportion of time spent in pairs or small groups was 0 percent for both Gilbert and McClure while it was approximately 10 percent for Fowler and above 20 percent for Baker. However, this number represents an oversimplification of the classroom environments of Gilbert and McClure. McClure's students were observed to work in groups on six occasions, but on those days the students spent a quarter of the time or less in groups. None of those occasions was a day when McClure indicated inquiry was occurring in her classroom. Gilbert's students were also observed to work in groups on six occasions, but on all but one of those days the students spent the majority of the class working in groups. Three of those occasions took place on days when Gilbert believed inquiry was taking place in the classroom.

Differences in Inquiry Lesson Structure

Even on days where they believed inquiry was present, the teachers differed in their use of classroom structures. McClure's students went back and forth in a single class between thinking on their own and meeting as a whole class. In Gilbert's classroom, students moved between working either individually or in groups (depending on the lesson) and meeting as a whole class. In Baker's and Fowler's cases, there were sometimes inquiry lessons that mixed time spent individually, in groups, and as a whole class. On other days, time was spent either individually or in groups (but not both) along with time as a whole class. The one constant among the four teachers was that on the

days when inquiry was occurring, some time was spent with the whole class meeting as a group, often at the end of instruction. However, there were no instances where an inquiry lesson occurred when the class met only as a whole.

In none of the fifty-six observations did any of the teachers stand before their students, deliver the lesson of the day while the students listened, and then ask their students to complete practice problems. In Brisbane, the *Everyday Mathematics* curriculum was not designed for teachers to deliver lessons in that way. The teachers in Adelaide could have taught from their textbook in such a manner, but chose not to do so.

Influences on the Implementation of Inquiry

This section addresses the one of the sub-questions of the study: What influences affect the teachers' implementation of inquiry? In particular, the study sought to identify the primary internal and external factors that affect teachers' usage of inquiry. Among the influences that tended to be viewed as negative were time and standardized testing. Textbooks were viewed in a mixed light. The most noteworthy positive factors identified were a sense of community between the teachers and the support of the MGM coach. Information reported in these sections was primarily collected from the second interview on external influences and from classroom observations.

Negative Influences Related to Time

The teachers in this case study recognized that teaching through inquiry would require them to dedicate extra time to particular lessons. This section begins with a discussion of the problems presented by the need for this additional time. The focus

shifts in the next section to how teachers attempted to meet the challenge of finding additional time.

Reducing Time for Other Subjects. In their background interviews, Fowler, Baker, and Gilbert spoke of taking time away from other subjects in order to have what they believed was sufficient time for mathematics instruction. In order to free up more time for mathematics, Fowler admitted to taking "fifteen minutes of this and fifteen minutes of that" in an effort to find an extra half hour for mathematics each day. She had tried to take some time from science and social studies but felt she had been largely unsuccessful. She had made the largest cuts to reading and spelling. She indicated that sometimes she was able to also combine reading with other subjects such as social studies so that the students had additional reading time. Regarding spelling, she said, "As one of my parents asked, 'Are you teaching spelling?' I said, 'Not so much.' Something had to go."

At Adelaide, the teachers also adjusted their daily schedules to increase the mathematics instructional time so that they could incorporate more inquiry-based activities. Gilbert and Baker both chose to cut a block of time devoted to silent reading. They indicated in their interviews that they felt their students' mathematics instruction had been compromised in the effort to produce better readers, evidenced by declining student scores on the math portion of the state criterion referenced test (CRT). Therefore, the Adelaide teachers felt justified in their decision to cut the extra time spent on reading. Furthermore, they indicated a willingness to make cuts to other areas of instruction if they felt it was needed in the future.

Preparing for Standardized Tests. Observations in Fowler's classroom began after the state criterion referenced test in accordance with a request made when she agreed to participate. She asked that visits not begin until after spring break because prior to that she would either be helping her students review for the CRT or administering the test itself to her students. Observations began earlier in the other three classrooms, but mathematics instruction ground to a halt in early March as the teachers used mathematics instruction time to review released mathematics items from prior years of testing. In Adelaide, Gilbert and Baker began regularly devoting twenty-five minutes of instructional time to CRT review nearly five weeks prior to testing. McClure chose a more concentrated approach where her students began looking at released items one week before the test, but the entire period was devoted to the exercises. The use of such time to prepare for the tests was notable in that it represented a loss of time that could have potentially been used for mathematical inquiry. As will be described later, some debate resulted from the discussion of whether or not inquiry was supported by the CRT testing in general.

Other School Events. A general lack of instructional time was evident over the course of the classroom observations. Fifteen weeks of observations extended over five months because there was not a single week in the study where every classroom was available for observation as had been originally planned. Changes in the daily schedule were a regular occurrence in all four classrooms due to conflicts with such events as the DARE program, an original opera production, a trip to milk a cow, orchestra day, vaccinations, and seminars on bullying. McClure and Baker both missed school to attend professional

conferences and McClure's committee work occasionally took her out of the classroom as well. Behavioral issues, while not pervasive, also took a toll. Baker lost the better part of a day's instruction because her students were caught trying to hold their breath until they passed out. There were also the small intrusions that added up over time such as students coming in from other classrooms to ask questions, especially at Adelaide Elementary.

Near the end of March, after CRT testing was over, Fowler indicated optimism at finally being able to focus on teaching. However, not long thereafter, she and the other teachers began to speak about how difficult teaching was due to the encroachment of summer. With picnics, retreats, award ceremonies, and extra field trips, instructional time (mathematics or otherwise) was restricted in May. For example, in Brisbane, it took nineteen school days to schedule observations for five days of mathematics instruction.

Extended Time for Lesson Preparation. Back at Brookings Elementary, Fowler described how the new textbook involved much more preparation time on her part. In the past, she had been able to look at the topic for the day and dive directly into instruction.

> Last year, sometimes when the bell would ring, I'd bring my kids in and I'd look at my lesson plans for the day. I always had my lesson plans there, but it'd say, you know, "This was the lesson of the day." I could flip to the day and take off. You cannot do that with Everyday Math. You're…sunk if you even… attempt that. So it's pretty quiet from eight to eight-thirty [laughing] in our hallway. Everybody's reading their math lesson for the day....

With the new text, Fowler is no longer simply presenting a topic to her students at the front of the classroom. Therefore, she must spend more time understanding the nuances of each lesson, what the students will be doing, and how to guide them along the way.

The teachers in Adelaide also expressed that they were spending extra time on lesson planning during the 2007-2008 school year. Baker said of the previous year, "I had it down pat…I didn't even pull out the teacher's manual…but I wasn't really doing what probably would benefit a lot of the kids." After her MGM experience motivated her to change her mathematics teaching style over the summer of 2007, she spoke of her planning in very different terms: "Basically, I'm reinventing the wheel. It just seems like I don't have a lot of time to do that." Gilbert spoke of how she had begun addressing lesson planning during that school year: "I think, 'How could I change that?' so it's been a lot of work to develop and create my own [lessons]."

Keeping Up to Pace. More so than in Adelaide, the teachers in Brisbane indicated feeling some pressure to keep moving through the text. In her second interview, McClure spoke of meeting with other fourth grade teachers in the district and learning that they were all within a week of each other in terms of their progress through the mathematics textbook. She mentioned that she would have been very distressed to learn that she was lagging behind the other teachers in the district.

Fowler indicated feeling a similar pressure to continue her march through the textbook. She stated that she felt she had been a better teacher earlier in her career when she felt she could stop and spend time on difficult topics or even go back to prior lessons when she thought her students would benefit.

Of all of the teachers, Fowler was the only one to routinely cite lack of time as a reason for not doing more inquiry in her classroom. She brought up the issue on seven separate occasions in the context of formal and informal interviews. In one snapshot

interview, she said, “Inquiry takes a lot of time and I don’t have enough of it.” During a lengthier interview, she pointed out cabinets of manipulatives that she felt she did not have time for the students to use in exploratory activities because she had too much to do.

Addressing Knowledge Gaps. In Brisbane, Fowler, McClure, and their students were experiencing the *Everyday Mathematics* books for the first time. Not only did the teachers have to spend more time preparing for class, the students also faced transitional challenges. Given the spiraling nature of *Everyday Mathematics*, the students in fourth and fifth grade were missing prerequisite knowledge that was assumed by the authors of the texts. Addressing these knowledge gaps used additional class time. In addition, McClure noted that her students were unaccustomed to doing much more than following a formula to find an answer, and initially had a hard time adjusting to the more conceptual thinking that the book required.

Addressing Time Constraints

The teachers in Adelaide and Brisbane found creative strategies for creating more time for mathematics in general and inquiry in particular. These are described in the sections below.

Extension of Mathematics Instructional Time. All of the teachers agreed that it took more time to teach a lesson incorporating inquiry than to teach the same lesson through direct instruction. The teachers at Brookings Elementary and Adelaide Elementary both increased the time spent on daily mathematics instruction; however, they overestimated their actual time of instruction. While they believed they used nearly seventy-five

minutes of time for mathematics per day, classroom observations showed that the two teachers at Adelaide Elementary spent approximately sixty minutes per day on mathematics. Fowler at Brookings Elementary did spend roughly seventy-five minutes on the subject based on observations and her daily schedules; however, she repeatedly stated in interviews that she was spending ninety minutes a day on mathematics with her students. McClure at Bartleby Elementary was the only teacher of the four not to increase her mathematics instructional time. Her mathematics classes, however, were already approximately seventy-five minutes in length with an additional 10 minutes of review that the students completed throughout the day.

Fowler said in her initial interview that the decision to increase math instructional time was due in part to her experiences at MGM, where she spoke with other teachers who were already using *Everyday Math* in their classrooms. Her thoughts were then reinforced by others in her district. Her decision to increase the time spent on mathematics was based primarily on the district's new curriculum and less on the desire to incorporate more inquiry into the classroom. After using the new text for over a semester, she stated in March,

> I don't know how I could do it [teach a lesson] in under 90 minutes. I really don't on this program. So, [it is] pretty rare that I go, "Oh, we can actually do this in under 90 minutes." That doesn't happen so much.

Overall, she indicated an increased emphasis on teaching mathematics.

> And we [the teachers] all kid about how when…anybody asks us, "What are you doing from this time to that time?" We just all say, "Teaching math." (laughs)…One of the kids went home, I think, and told her folks,... "All we do is math," (laughs) and it feels that way sometimes, but at the same time, too, the kids are engaged and they don't seem to be losing focus and interest in it even though it's a longer time, it's a busy time.

Baker and Gilbert at Adelaide Elementary also indicated that their decision to increase the mathematics instructional time was due in part to their experiences at MGM. Baker said that she had been advocating for such a time increase for several years because she had seen its benefit while student teaching in another district; however, the principal did not feel that research supported such a change. After talking with other teachers at MGM, Baker, Gilbert, and a third Adelaide teacher were able to make a stronger case. She continued, "We went to the math thing this summer with the MGM grant and we discussed it and…we basically convinced them."

Reduction of Topics. In their background interviews, the Adelaide teachers described how they made a concerted effort to change how they taught mathematics in their classrooms. Part of this change involved revising which topics they covered. In her background interview, Gilbert described how they had ceased moving straight through the text. She said, "The junior high and the three of us sat down and made a pacing chart and said, 'Okay. What do we need to teach? What are you teaching? What do they need to be prepared to do?' and since then, we've also looked at our curriculum [and] our standards." The teachers were trying to put more thought into exactly which topics were covered in their classrooms.

This streamlining of the curriculum was accomplished with encouragement and support from Dr. Carr, the MGM coach assigned to Adelaide. The fifth grade teachers eliminated a number of lessons from the text that were not included in their standards or which were duplicated at a higher grade level. Baker described the process of reducing coverage:

> We'll say, 'Okay, why did we need to do multiplying mixed fractions?' They [the students] have to have a basic understanding of what a mixed fraction is. Why did we go from mixed fractions to adding them, subtracting them, multiplying and dividing them? Those were four lessons – probably two weeks of learning that we can turn into something that they need to know like geometry. We never did enough [geometry] and we found out through these benchmarks and standards that is something they needed to know, so we took those four weeks out of lessons that were in the curriculum and we focused on it [geometry].

In another interview, Gilbert went on to say, "Before, I used to be afraid of standards. Now I'm thinking, 'Why didn't I look at them a long time ago? I could have thrown all that stuff out of here."

Gilbert described the excitement she and the other teachers felt about eliminating extraneous topics: "It's just like, 'ahhhhhhh,' [breathing a long sigh of relief]. And we knew we were getting rid of that book so it's just like put a big 'X' through it and we're like, 'Yay!'"

Over the course of the observations, neither Baker nor Gilbert ever mentioned that they felt pressed to get through the fifth grade mathematics curriculum. On the topic, Baker said, "I think I have the time. It's just split up. That's fine." The split she was referring to was the daily forty-five minute break in the middle of mathematics instruction. Gilbert said, "I think I usually have enough time. If I don't finish one day, I'll tell them, 'Okay, think about that. We're going to be working on it again tomorrow." In addition, observations showed that at the end of the school year, the teachers were able to spend more than a week on probability, a topic they had never been able to reach in the past.

Creative Collaborative Planning. The MGM coach encouraged the Adelaide teachers to work together and support each other in their mathematics teaching. The three fifth grade teachers met for lunch every Friday during Spring 2008 to talk about mathematics and share lesson ideas, a commitment they had never made before. In her second interview, Baker discussed a recent meeting:

> Last time, we did talk about how probability's coming up and we decided that we were going to do a carnival theme to wrap up probability, ratio, and scale. And so we're working on that right now. The only problem is that we've had to go to this back little room because we're always bothered and we have to meet during lunch together.

In another effort to find time to meet together, Baker realized that she could use her class time more efficiently. On occasions when she planned for her science students to watch a video, instead of having the three classes watch independently, all of the students met in one room under the supervision of an aide. At the same time, the three fifth grade teachers could meet in another classroom and discuss mathematics. In an informal interview, Baker emphasized that she was using the same science instructional materials that she would have been using ordinarily but in a more effective manner.

Influences Related to High Stakes Assessments

While not unrelated to the time factor, standardized testing played its own role in influencing the use of inquiry in the classroom. The amount of time dedicated to standardized testing varied between the districts. All schools participated in the mandatory state assessments which took place over the course of a week in March. As part of a larger district with more regulations, the schools in Brisbane had an additional two weeks of testing due to mid-year and end-of- year assessments.

McClure and Fowler in Brisbane acknowledged that some teachers in their district rushed the curriculum to try and get through more material before standardized testing took place. Others had taught geometry lessons out of sequence in order to cover the topics before testing. Both teachers claimed that they had resisted the urge to rush lessons or teach out of sequence. McClure was unsure whether she would resist that temptation in the future but wanted to be loyal to the *Everyday Mathematics* program for at least the first year.

The teachers in Adelaide made a concerted effort to cover geometry topics before the state assessment. As part of their efforts to align their curriculum to the state standards, the teachers also adjusted the order of instruction so that they would be able to cover the geometry topics earlier in the year. As their curriculum did not spiral, the teachers were not concerned about disrupting the continuity of instruction.

There was no clear consensus among the teachers as to whether or not the state assessment supported the use of classroom inquiry. Gilbert and Baker felt that the constructed response items on the state assessments gave them more incentive to use inquiry in the classroom. They felt inquiry helped the students to reason mathematically and therefore set them up to be more successful on the two constructed response items where students had to not only find a solution but also justify their process. Gilbert mentioned that she considered using inquiry as one way of teaching to the test (although not to particular questions) since the students would need inquiry skills for the constructed response questions. In contrast, McClure felt that nothing related to standardized testing could be considered inquiry itself or could support inquiry.

Influence Related to Curriculum

Adelaide Elementary School used *McGraw-Hill Mathematics* (2002), a traditional textbook series, while the teachers in Brisbane had adopted *Everyday Mathematics* (2007), a reform or standards-based text. Further descriptions of the features of traditional and reform texts can be found in Chapter 3. The curriculum influenced teachers at the two schools in different ways.

Adelaide - Breaking Away from *McGraw-Hill Mathematics*. While at the MGM summer institute, all of the participant teachers brought their mathematics texts and met in groups by grade level to decide for themselves which series they believed best supported classroom inquiry. From this experience, the Adelaide teachers decided that their text was the worst at supporting inquiry when compared with the texts brought by other teachers in their group. After this realization, the Adelaide teachers decided that they could no longer utilize their book as they had in the past.

Previously, they had progressed section by section through the *McGraw-Hill Mathematics* text without omitting any major topics. From the front of the classroom, they would present the daily lesson to their students much as it was outlined in their teacher's manual. With the advent of the 2007-2008 school year, they began using their book more as a list of possible topics to cover and a source of practice problems. The teachers no longer wanted to simply present the mathematics material to their students. However, Gilbert and Baker were unable to rely on the text as a source for meaningful activities for their students or for the creation of inquiry-based lesson plans. Instead, the

teachers began to rely on each other, their MGM coach, the internet, and their own imaginations for lesson ideas.

The fifth grade teachers in Adelaide began pushing to procure new mathematics texts for their school that would better support inquiry. Adelaide Elementary was not scheduled to purchase new mathematics books for another year; however, the fifth grade teachers felt that it was important to replace the mathematics books as soon as possible. In order to hasten the schedule for replacing the books, the teachers had to rally the other elementary school teachers so that they, too, would push for a new mathematics curriculum. The process of gaining the support of their fellow teachers, of the principal, and of the school board, and finally selecting a new curriculum took the entire school year. Although they tried to remain open to other curricula, the teachers were somewhat predisposed to the *Everyday Mathematics* because of how well they felt it had stood up against other texts during the textbook comparison at MGM and because of how highly the other teachers spoke of it at MGM. In May, Baker was finally able to report that the teachers had received final approval and an order for the *Everyday Mathematics* books had been placed.

Brisbane - Maintaining Fidelity to *Everyday Mathematics*. The teachers in Brisbane were using the *Everyday Mathematics* text in their classrooms for the first time. Unlike past years, the students did not have a textbook to use; instead, they had what the authors called a journal although it closely resembled what is traditionally called a workbook. For each lesson, the student journal contained a page of Math Boxes (composed of

review or extension problems from previously covered topics in the curriculum) and a few pages of investigation or questions for the students to complete.

McClure and Fowler both gave their students about fifteen minutes to work on their Math Boxes on most class days. Students would complete the review problems first thing in the morning while daily tasks such as the collection of lunch money, roll call, and announcements were taking place. McClure said that when she found she had extra time, she would use her overhead projector to go over the day's problems with her students but did not make it a priority. Fowler would typically go over at least some of the Math Boxes with her students on a daily basis. She encouraged more critical thinking by having students provide answers, confirm them with others, and support their thinking. Only after this review was completed would Fowler transition the students into the true mathematical lesson of the day.

Students also had a Student Reference Manual where some of the material, including formulas, was presented. It also included charts, graphs, and other data for students to use in lessons as well as the rules for the mathematics games. Students rarely used the books for the formulas or worked problems. Instead, the manuals were used most often for their game rules and for their general reference data (e.g., the population of the United States in the 1700s).

Games are intended to be considered an integral part of the *Everyday Mathematics* curriculum but can be easily misused. Fowler decided to make every Friday a game day in her mathematics class since the students had difficulty concentrating on those days anyway. Students would also occasionally play games on other days when

she felt a particular game was especially useful or when there was a little extra time. McClure used the mathematics games in her classroom very infrequently as they were an aspect of the curriculum that she had struggled to find time to incorporate in the first year. Her students played the math games only when there was extra class time or, at least in one case, when the students needed extra practice on a topic.

For at least their first year with *Everyday Mathematics*, McClure and Fowler had both agreed to teach straight through the book without omitting any topics. McClure stated on the first day of observations that she had been advised by teachers already using *Everyday Mathematics* "to trust the program because it works." She decided to do so faithfully for the first year. McClure never deviated from the text. Fowler, on the other hand, chose to teach the topic of adding and subtracting integers using a different approach than the monetary context that was advocated by *Everyday Math.* Both teachers acknowledged omitting certain parts of individual lessons due to either lack of time or a lack of need on the part of the students, but they otherwise proceeded directly through the text

The level to which inquiry was tied to the *Everyday Mathematics* text, at least in the minds of the teachers in Brisbane, cannot be overemphasized. This does not mean that the teachers considered everything in the text to be inquiry related. However, when asked a question about inquiry during interviews, McClure and Fowler would both invariably drift into a discussion of *Everyday Mathematics* or couch their answers in terms of the series.

Influences Related to Community

None of the teachers in this study was completely isolated in her school. However, the sense of mathematical community was strongest in Adelaide. In Brisbane, it was impossible to separate the teachers' discussion of inquiry from their text. In Adelaide, the trouble lay in separating the teachers from one another. Adelaide was selected for the case study, in part, because all five teachers representing grades 5-8 mathematics had participated in MGM. No such "critical mass" existed in Brisbane. At Brookings Elementary where there were three fifth grade teachers, Fowler and one of the other fifth grade teachers were part of MGM. At Bartleby Elementary, McClure, a fourth grade teacher, participated along with a fifth grade teacher although the school had two teachers at each of those grade levels.

Brisbane – an Independent Approach. All of the teachers in the study commented on the support they received from the other teachers at their grade level. But the impact of having fellow MGM teachers at the school varied between the participants. In her initial action plan reports, McClure made it sound like she worked rather closely with the other MGM teacher at her school. However, in subsequent interviews she admitted that she actually discussed mathematics and teaching with this other teacher very little, noting that their working styles were so different she felt it was difficult for them to be of much help to each other.

McClure did have other forms of support. She attended required weekly meetings with the other fourth grade teacher, with whom she would discuss the basic outline of her lessons. In addition, she worked closely with Ms. Buck, the teacher of students with

disabilities, who helped her students during mathematics lessons and was also a personal friend. McClure, however, never mentioned sharing lesson ideas with Ms. Buck or talking with her about mathematics teaching in general.

Interactions between Fowler and her fellow fifth grade teachers were never observed beyond a few snippets of friendly chatter before the start of school. In interviews, Fowler mentioned that the support of these teachers helped her in making the transition to the new curriculum. In her mid-year report on her action plan, Fowler specifically mentioned Ms. Avery, the other MGM teacher from fifth grade:

> One of the biggest helps and support for achieving my goals has been my colleague across the hall that has also attended MGM. She and I…give each other tips and heads up as to problems we've encountered. We share our successes as well as struggles.

According to Fowler, the fifth grade teacher who had not participated in MGM had been resistant to *Everyday Mathematics* and continued to teach very traditionally. This teacher was not open to the new ideas that Fowler and Avery had brought back with them from MGM. As a result, while all three teachers were still on good terms with one another, Fowler was much more apt to discuss teaching mathematics with Avery. In her first interview, Fowler said,

> [Ms. Avery] and I tend to talk with each other more than we do perhaps with the third teacher. I think the third teacher does tend to teach more in maybe a traditional way. I don't know that she…. Ms. Avery and I are probably a little closer in our styles. Let me put it that way.

Adelaide – a Collaborative Approach. In Adelaide, all three of the fifth grade teachers had participated in MGM and all three agreed that they needed to change how they had been teaching mathematics. They presented a united front to the administration

in their quest to obtain a new mathematics text. The unity of these teachers was evident from interviews and from comments made in passing. For instance, Gilbert said in her first interview, "Well, Ms. Lee, Ms. Baker, and I get along really well. You know, we all have our own, I'm sure, strengths and our weaknesses; but we help each other out." Baker shared a similar opinion in her first interview, "I think we [the fifth grade teachers] get along so well that it really affects us as a group and how we teach."

The interconnectedness of the teachers was also evident from weekly observations. For two different series of lessons (one on the metric system and another on fractions), instead of teaching mathematics to their own students as they would normally do, the three teachers created stations in each of their classrooms. The students from the three classrooms then rotated through a mini-lesson or activity run by each teacher in her own classroom.

On another occasion, Baker and Gilbert combined their students for a discovery lesson on the properties of triangles using an applet on Baker's computers. Gilbert had computers in her own room but wanted to teach the lesson with Baker, who felt more comfortable working with the technology.

Even when not teaching together, the Adelaide teachers shared lesson ideas with one another. Gilbert, in particular, provided ideas for the other teachers such as a lesson using Uni-fix cubes to support a discussion of volume or an assessment on area and volume where the students had to design their own parks.

Improved Communication in Adelaide. The teachers in Adelaide had a good working relationship before MGM. However, it was not until after the MGM summer institute

that they began talking about the teaching of mathematics. Even this discussion did not occur as frequently as they had envisioned at the time they were leaving MGM. Eventually, their MGM assigned coach, Dr. Carr, succeeded in convincing them to meet every Friday over lunch to discuss mathematics. In justifying her efforts to increase communication, Dr. Carr noted that among the three Adelaide teachers "often the left hand doesn't know what the right hand is doing."

Beyond increasing communication with each other, the fifth grade teachers felt better able to talk about mathematics with the junior high teachers who had also participated in MGM. While the teachers had spoken with each other prior to MGM, they never spoke directly about mathematics. In Fall 2007 following the MGM summer institute, Gilbert and Baker both spoke of talking with Mr. George, the seventh and eighth grade mathematics teacher. He had begun introducing more inquiry into his classroom even before the summer institute, motivated by an introductory MGM weekend workshop that took place in Spring 2007 before the summer institute.

Gilbert discussed how she had relied more heavily upon Mr. George in the fall of 2007 but gradually became more independent and able to incorporate inquiry into mathematics lessons on her own. In her first interview, Gilbert said,

> I used to go to Mr. George and say, "I want to do inquiry based but how would I do that with this one?"… I feel more confident now. I still use him but I've come a little further. I've learned how to be calm and think, "Maybe I can do that."

Because it resulted from her growing facility with inquiry-based mathematics instruction, Gilbert's decreased communication with Mr. George can be viewed in a positive light.

Expansion of the Mathematical Community. Although they were never asked to do so as part of their participation in MGM, the three fifth grade teachers in Adelaide and the two MGM teachers at Brookings Elementary took on new leadership roles after their participation in MGM.

Ms. Fowler and her fellow fifth grade teacher, Ms. Avery, shared their new knowledge of inquiry with teachers at their school during a mathematics professional development seminar. In a mid-year report, Fowler wrote,

> Due to my participation in MGM, my principal now turns to my coworker that also attended MGM and myself for information about how our new math program is faring related to what we've learned. We've also been asked to present a portion of an early release inservice to the rest of our staff on what we've been learning through MGM.

Not only was Ms. Fowler invited to share her knowledge of mathematics and inquiry with her fellow teachers, she felt that her principal had also begun to turn to her as a source of valued feedback.

The teachers in Adelaide mobilized colleagues at their school to press for permission to purchase a new mathematics curriculum. Baker described speaking with fourth grade teachers who were concerned about the transition to a reform curriculum. She told them how she and the other fifth grade teachers had been in their shoes only a year before, that they would support and guide the fourth grade teachers as they learned to incorporate inquiry into their teaching with the new curriculum.

After her final interview, Baker commented on the need to continue to extend their mathematical community even on a local level. After struggling for most of a year to convince the school to adapt the new mathematics text, she belatedly learned that the

high school (which adjoins the elementary school and junior high schools) had been using a reform-based mathematics text from the University of Chicago (where *Everyday Math* originated) for a few years. She could not believe it took her less than five minutes of conversation to learn this information. The high school teachers were located literally next door, but she had never taken the time to speak with them.

Influence of Coaching

As part of the follow-up activities that occurred during the 2007-2008 school year, all twenty-four of the MGM participants were visited at least four times by a coach. Ideally, the visits were supposed to occur quarterly but did not in all cases due to the extreme distances of five hours or more between some of the coaches and teachers. For the teachers in this case study, the coaches were within an hour or less of the teachers and quarterly visits were not problematic.

The coaches were either expert middle school teachers or mathematics educators from a state university. The only notable exception was Dr. Carr who had previously spent twenty years teaching in the classroom and had earned a doctorate in education (EdD). Dr. Carr performed outreach work for the state university but was not formally a member of the faculty.

In a survey completed before leaving the 2007 summer institute, Fowler, McClure, and Gilbert expressed their anticipation about receiving feedback on their usage and understanding of inquiry. Coaching during the academic year 2007-2008 was viewed positively by most of the teachers. At the end of the MGM project, participants were asked to identify the aspect of MGM which they felt best supported their use of

classroom inquiry. Most inquiry chose to highlight the original 2007 summer institute. However, coaching was identified as the most instrumental follow-up activity in supporting inquiry.

The teachers in this case study had three different coaches. McClure's coach was a middle school teacher as was Fowler's coach. Dr. Carr coached Baker and Gilbert as well as the other three MGM teachers at their school. All four teachers in the case study spoke positively of their coaches. McClure taught lessons while her coach observed and also had the opportunity to observe her coach teach a model lesson. The same was true for Fowler. Baker and Gilbert also taught lessons while Dr. Carr was present; although they did not observe her teaching, they worked on curriculum together. The roles of all three coaches extended beyond mere observation of classroom instruction.

Initially, the teachers admitted to being nervous about having someone come and observe their classes. They were afraid they were being judged. This was true for the teachers in this case study as well as for many of the other MGM teachers. However, the teachers in this study came to realize that the coaches were there to provide support rather than to criticize. They were grateful to have someone in the classroom whom they felt was truly in their corner. In her initial interview, Gilbert said, "I consider her like a mentor or a coach like because she's not really here to critique us," and later added, "I used to be nervous. Now, I look forward to her coming."

In addition, the teachers noted that the coaching visits served as a nice reminder to implement their action plans and to provide help in how to go about the implementation. Gilbert and Dr. Carr both stated in informal interviews that Gilbert had been especially

concerned about implementing the technology portion of her action plan. Therefore, Dr. Carr suggested that Gilbert and Baker plan a lesson together so that it would be less formidable for Gilbert.

All four teachers mentioned having received research articles from their coaches, although the only articles in evidence came from Dr. Carr. In addition, they supplied lesson ideas. For example, when the fifth grade Adelaide teachers decided to move their geometry unit to an earlier point in the year, Dr. Carr brought them geometry activities from two different textbook series they could potentially use them in their classrooms and have the opportunity to peruse different texts that they might be considering for the upcoming year.

The teachers in Adelaide were pressed by Dr. Carr to improve their communication with each other. In an informal interview, Dr. Carr mentioned how she saw essentially the same lesson on fraction addition in the fifth, sixth, and seventh grade classrooms. Even at the same grade level, the teachers were not communicating effectively about the activities they were using in their own classrooms. Dr. Carr felt that the three fifth grade teachers were using fraction activities that would tie together nicely for their students, but such connections could not be made because the teachers were not giving each other sufficient information about what they were doing. With her encouragement, the fifth grade teachers began meeting weekly to talk about mathematics.

The teachers in Adelaide were able to streamline their curriculum by aligning it to the state standards. The alignment process took place due to the encouragement of Dr. Carr who spoke from her years of experience as a curriculum leader and suggested that

there was a need for the action. The teachers were able to arrange for a half-day release to meet with each other and Dr. Carr to make the final decisions on which topics should be taught. Such meetings and similar long-range planning were not evident with the other coaches.

Dr. Carr's coaching of the teachers at Adelaide appeared to be far more influential than that of the coaches at the other two schools. In part, this influence may well have been attributable to the amount of time that Dr. Carr spent with the teachers in Adelaide. The coaches of the two Brisbane teachers were middle school teachers with classrooms of their own. Dr. Carr had the flexibility and freedom to spend more time with the teachers in Adelaide than other coaches had to spend with their teachers. Dr. Carr went far beyond the MGM expectation of four coaching visits lasting roughly two hours. She would visit repeatedly over the course of three or four days. She would meet with the teachers a few days in advance to discuss their plans, return for the teaching of the lesson, and then meet again with the teachers afterward. Her repeated visits over a short period of time gave the teachers more opportunities to work with her and provided more opportunities for her to give feedback, whether on a particular lesson or more generally.

Planned vs. Enacted Lessons

From the classroom observations, another influence began to emerge. In some cases, lessons that were designed to incorporate inquiry seemed to backfire, despite obvious opportunities for exploration and discovery. This happened in McClure's classroom when students were investigating how to reconfigure parallelograms in order to find the area and in another lesson when the students were supposed to look for

patterns in the volumes of rectangular prisms. A similar phenomenon took place in Fowler's class in a lesson where students were to find the area of a triangle using what they knew about rectangles. These three lessons provided students with opportunities to explore, investigate, and make discoveries. However, in each instance, the process of inquiry derailed.

Initially, students followed the directions they were given. They were actively drawing and cutting out shapes but they struggled to form hypotheses that they could test even informally. They students continued making new shapes until they became bored and then either sat staring at their papers or began chatting with friends about non-mathematical topics. Noting when students largely lost interest in the lesson was particularly easy in McClure's classroom, as they started bobbing on their yoga balls.

In all three cases, the teachers were aware that their students were stuck. During the volume lesson, McClure provided some guidance to her students to help them progress by identifying a pattern. However, in all three lessons, the opportunity was brought to an end when the teachers were identified one person who had made the desired discovery of the day. The final result was presented by that student, after which the teachers acted as though the goal for the day had been reached. There was no additional questioning or discussion involving the other students. It was clear that the other students in the class did not yet understand the results, as evidenced by confused expressions on their faces and, in the case with the lessons on area of parallelograms and on area of triangles, by their inability to complete any of the practice problems.

Summary

This section presented influences, both positive and negative, that impacted the teachers' usage of mathematical inquiry in the classroom. Teachers felt they needed more time to utilize inquiry adequately in their classrooms and they sought out possible ways to create more time for mathematics instruction. Teachers in Brisbane identified their textbook as supporting their use of inquiry while teachers in Adelaide felt their text was a hindrance. Despite the challenges posed by their textbooks, the teachers in Adelaide used their local community of MGM teachers and their coach to modify their mathematics teaching and include more inquiry. The next section begins to address questions about teachers' perceptions about and use of inquiry, by examining evidence of inquiry-based teaching in the classrooms of the four teachers.

The "Is it Inquiry?" Interview

Over the course of observing the four teachers "in action" during mathematics lessons, it became apparent that comparing and contrasting their instruction was made difficult by how lessons varied from class to class. This motivated the creation of a task-based interview designed to reveal each teacher's interpretation of inquiry. During the interview, each teacher was shown the same set of activities. The teachers were asked to discuss whether or not they believed that mathematical inquiry was supported in the completion of each of the activities and to justify their responses in each case. In the event that they did not feel mathematical inquiry was present, the teachers were also asked whether or not they felt that the particular activity could be modified to better support inquiry. The teachers were shown a total of eight activities. One activity, the

Spinner Game, was selected with the expectation that they would all identify it as inquiry. Similarly, the Place Value Item was selected with the assumption that none of the teachers would identify it as an opportunity for inquiry. The other activities were selected in the hope that they would help to differentiate exactly what the teachers considered to be (and not to be) inquiry. A copy of each of the activities can be found in Appendix G.

Results from "Is It Inquiry?" Interview

In the paragraphs that follow, the teachers' responses will be described in the order that the tasks were presented to the teachers in their interviews. Table 3 provides an overview of the teachers' responses. Note that Baker classified most activities as inquiry and McClure classified only two activities as inquiry. Fowler's and Gilbert's responses were somewhere in the middle.

The Spinner Game**.** In this activity, students were asked to consider a two-player game where players take turns spinning two spinners (one with the digits 8, 3, and 4 and the other with the digits 0, 1, and 4). One player wins if the sum is even and the other wins if the sum is odd. Students had to decide whether or not the game would be fair and to describe how they knew which child would have the better chance of winning.

All four of the teachers felt that this activity lent itself to classroom inquiry. Baker and Fowler stated that requiring the students to explain why the game was fair or not turned it into inquiry. Fowler, Gilbert, and McClure stated that the students would be able to discover whether or not the game was fair through experimentation. Gilbert said, "[The students] would come to that conclusion…by working through the math and

Table 3. Teacher Response Overview from "Is It Inquiry?" Interview

	Teacher			
Activity	Baker	Fowler	Gilbert	McClure
Spinner Game	Yes	Yes	Yes	Yes
Place Value Item	No	No	No	No
Parts of a Whole Activity	Yes	Yes	Yes	No
Toothpick Problem	Yes	No	Yes	No
Distance From Home	Yes	No	N/Yes	No
Park Design	Yes	N/Yes	No	No
Volume Formula	Yes	Yes	Yes	Yes
Turtle Plotting	No	Yes	N/Yes	No

Note. N/Yes indicates an initial No answer eventually changed to a Yes answer.

actually doing the work and spinning….They'd come to it on their own without me telling them, 'Well, this is this and that's why.'" Fowler went on to say that she could extend the inquiry in the activity by asking her students how they could make the game fair.

The Place Value Task. This object of this task was to give the numerical representation of a number that was written out in words. It was a multiple choice item from a fifth grade- level criterion referenced test. All four teachers were unanimous in stating that this item did not lend itself to inquiry. McClure indicated, "That's just doing… that's just computation…It doesn't show meaning and they're not learning

anything from doing it other than how many people go to the state fair which isn't mathematical." Fowler and Gilbert both focused on the idea that students were merely recalling prior knowledge.

Also worth noting were the teachers' responses when asked if they could somehow tweak the problem in order to better incorporate inquiry. While not necessarily indicative of their abilities to implement inquiry in the mathematics classroom, the teachers' responses did reflect their attitudes toward inquiry that were confirmed by other data. Fowler's response echoed her concerns about time: "I suspect there is a way to tweak anything…to turn it into inquiry. However, I would not spend my time doing it on this particular question." McClure commented, "Not that one. I mean, that's just a straightforward, computation basic run of the mill story problem." Gilbert said, "I don't know. I'd have to ask for help," which demonstrated her uncertainty about using inquiry, even though classroom observations showed she was creating lessons which incorporated inquiry. Baker was the only one of the four to pose a suggestion by saying, "You could probably incorporate it into a bigger problem and [ask], 'How many different ways can you show this number?' and have them discover and do different things… I would relate this to equivalent numbers and fractions and decimals."

Parts of a Whole Activity. In this hands-on activity, students used pattern blocks – relatively sized hexagons, trapezoids, parallelograms, and triangles - to tile larger shapes which were considered to be one whole. The students then had to determine what fractional part of the different wholes was represented by the pattern blocks.

All of the teachers believed that this activity lent itself to inquiry with the exception of McClure even though this activity came from McClure's classroom. McClure said, "I don't think this is necessarily inquiry. I think this is one of those experiences that they definitely gain things from but I don't know that there was one great mathematical concept that really came out of this activity." She went on to add that many of her students had difficulty in future lessons because they became stuck on the notion of using a hexagon as a whole. She did believe that the students had constructed meaning from the activity, but she did not think that inquiry was involved.

The other teachers all thought the activity did support inquiry. Baker spoke of how children would have the opportunity to discover the inter-relatedness of various shapes. Fowler said, "This one happens to use manipulatives that they can actually use and not all inquiry does…so I think this would be a great lesson with fractions and equivalent fractions." While developing a notion of equivalent fractions was not a goal of this particular lesson, McClure noted that some of her students had grasped the idea while doing this activity. Fowler felt that the opportunity "to question and to predict" about the fractional parts and equivalent fractions while using manipulatives made the activity well suited to inquiry. Gilbert also noted that the use of manipulatives made the activity more inquiry-based.

Toothpick Problem. All four of the teachers utilized logic puzzles and brain teasers in their classrooms, therefore, a sample brain teaser question was included in the interview to determine whether or not the teachers considered these sorts of problems to be inquiry-based. In this example, the students see an equilateral triangle formed by three toothpicks

and are asked if they can think of a way to construct four equilateral triangles out of only 6 toothpicks.

The Adelaide teachers believed that this item would be indicative of inquiry whereas the Brisbane teachers felt otherwise. Gilbert said, "They have to manipulate and try things and figure it out by trial and error and then [come] to a conclusion on their own instead of me telling them." Ms. Baker echoed Gilbert's sentiment and then went on to say that inquiry was supported by "the fact that they have to have a thought process...not just even hands on but think beyond just the term equilateral triangle. You know, they have to try to discover, is it possible?"

Fowler and McClure felt inquiry was not supported in this problem because the students already had to know what an equilateral triangle was before approaching the problem. As McClure said, "I don't think that that would be [inquiry]….They'd already have to know what an equilateral triangle is, so I don't know what great concept they'd learn from doing that." Both approved of the activity, but not as an example of inquiry. Fowler was particularly focused on the lack of a clear objective when completing this problem.

> I guess I would want to know what the purpose is before I actually said, "No, it's not inquiry," or "Yes, it is." Why am I using those toothpicks? Is it just a fun activity or is it for patterns? …But if it's "Can you do this?" I don't think that necessarily puts it into the category of inquiry for me.

Distance From Home. This was a released item from the state's criterion referenced test. It was included because Gilbert had mentioned in a snapshot interview that she felt it required mathematical inquiry. While it was multiple choice just like the item on place

value, the level of difficulty was considerably higher. The Adelaide teachers admitted that they, too, had to think about the question when they first encountered it with their students. Once again, opinions on this item were split between the teachers in Adelaide and the teachers in Brisbane.

Fowler and McClure felt that the item was an assessment of prior knowledge. As Fowler said, "I don't see so much inquiry here but a great little assessment to see if they can read a graph like that one." McClure did not see potential in changing the problem to incorporate more inquiry. She said, "There's no concept being gleaned from anything here… even if you had them draw the graph, they'd have to have already learned the concepts of graphing beforehand." Fowler felt that inquiry might be incorporated if the students had been drawing the graph themselves.

Baker felt that this problem required more thought than was immediately apparent. She said, "It doesn't look like it's inquiry but I think it is because you have to get the kids to just reflect on their thoughts." She did, however, acknowledge that the difficulty of the problem meant the students would need encouragement from her in order to persist. Recounting the experience of doing this problem in her classroom, she described of telling her students, "'You need to think about it.…Put down your [pencil] and then think,' and then there were a bunch of kids who went, 'Ohhhh.'"

Gilbert at first stated that she did not believe the problem could be used for classroom inquiry: "It's too advanced to go into an inquiry." However, as she discussed the problem, she changed her mind and decided that the problem did lend itself to

classroom inquiry as long as she could appropriately scaffold it for her students in order to make it more approachable for them.

> I could do a different inquiry-based lesson. That's why I changed my mind…You could talk about what's happening in each of these situations…going further away from home and not stopping anywhere or he's going further away from home, staying there for a while and then going onward….They could come to those conclusions by kind of looking at this with some guided questions, I think. So that probably would be a good lead in lesson for an inquiry base.

Park Design. This activity was created by Gilbert as a summative assessment for her students. It was also used by the other fifth grade teachers in Adelaide. A rubric that the students were given at the time the assignment was made is included in Appendix G. In the activity, each student was asked to design a park with certain required elements such as a picnic area and a pool and to utilize shapes that had recently been studied in the geometry unit. The students drew their designs on large sheets of grid paper and wrote a short paper discussing their designs as well as their calculations for the area of four objects in their park and the volume of their swimming pool.

> Baker felt that this represented a different type of inquiry where students
>
> …[H]ad to take all these different concepts and put it into something that could be like a real [world] job….They had to take many different… math\ geometric ideas and put it together in [a] project in a way that our book wouldn't allow.

She thought that presenting it as a summative activity would help the students to form new connections and learn how to apply their knowledge in a way that employed mathematical inquiry.

In contrast, McClure did not believe inquiry could be part of a summative assessment such as this. She said,

> In order to do it they already have to know what area is and they already need to know what perimeter is and they already need to know what volume is so I don't know that they would be learning any new concept out of doing this project.

When asked for clarification, McClure said that students needed to be learning the concepts for the very first time in order to inquiry to be taking place.

Somewhat surprisingly, Gilbert agreed with McClure that the activity did not really involve inquiry, although it she did take time to ponder her explanation. Gilbert had struggled with whether or not the activity was actually inquiry at the time she gave the summative assessment in class. During an observation, she had expressed concern that the students were only going to be working on their assignments and she did not think that they contained mathematical inquiry. She changed her mind after discussing the activity with Baker; however, she did not seem as confident in her response. In the task-based interview, after some internal debate, she returned to her original belief that the activity was not really an example of mathematical inquiry. She started with, "It could be inquiry based in the fact that they had to manipulate their previous knowledge to put a project together," before eventually arriving at, "They used old knowledge or previous knowledge…so not so much….They already had all that knowledge and they just had to build a project from it to show me their knowledge."

The park design activity also posed some difficulty in classification for Fowler. Initially, she answered quickly and decisively.

> Great assessment. Inquiry? I don't think so because if I'm understanding the way this is, they're using their knowledge of what they've already achieved throughout this unit to now incorporate it into the practical part…to show their skill…but I don't think that they're going with so much a question in mind.

The interview moved on to consider other items, but Fowler continued to keep this activity in the back of her mind and began to rethink her answer in light of her comments on subsequent items. Therefore, near the end of the interview, she asked to change her answer on this item. "I think actually this would be a good one. Not only as an assessment but a great one to say, 'How are we going to do this?' and to question and to discover and to connect." She felt that the students' need to understand the application helped to turn it into mathematical inquiry.

Volume Formula. In the lesson prior to this one, students had built nets out of centimeter grid paper. In this volume activity (taken from McClure's classroom), the students were given more grid paper to use in constructing open topped boxes of varying sizes. The students then filled the boxes with centimeter cubes and noted the number of cubes that it took to fill the box (i.e. the volume) on the bottom of each box. The intent of this activity was for students to develop an understanding of the concept of volume.

The four teachers agreed that this lesson could easily be used in a classroom inquiry. As McClure said, "This activity was totally inquiry because they knew what volume was by the end of it. They knew how to calculate it on their own and I did not get up and say, 'Well, guys, today you're going to multiply the base times the height.' They figured it out for themselves."

Gilbert expressed a desire improve the lesson by posing a question to the students earlier in the lesson, much as she had done with her own students, where the students had to predict how many cubes it would take to fill a big box without actually filling the entire box with cubes.

When this lesson was observed in McClure's classroom, the students spent the majority of the class cutting out different nets and filling them with cubes. However, students were not reaching conclusions about volume. With only a few minutes left in class, McClure went to the board and started asking students to provide her with the dimensions of different boxes they had constructed as well as the volume they had found. McClure wrote the findings on the board in an organized fashion and then asked the students to see if they could find a pattern to the numbers. In less than a minute, a student suggested that the volume was the product of the three dimensions.

This activity was included in the third task-based interview in order to ascertain whether the four teachers felt the lesson could still be considered inquiry after the added guidance given by McClure. Once again, the four teachers were in agreement that the activity, even with scaffolding, exemplified mathematical inquiry. Fowler said, "I think that you can put those [the dimensions and volumes of different boxes] there and as long as I'm not saying, 'It is length times width times height,' I think there is a lot of inquiry." Baker concurred and added, "They need direction. Again, in guided inquiry…especially because a lot of these kids aren't used to full inquiry, they're going to need some direction."

Turtle Plotting. In this activity taken from Fowler's classroom, students were given a small drawing of the outline of a turtle as well as a coordinate grid. They were given the coordinates of the turtle's nose and were asked to plot points and connect them in order to create their own turtle on the grid. As the students primarily used whole number coordinates, the resulting turtles were very boxy and not exact duplicates of the one shown on the page.

Reactions to this activity were divided between the more experienced and less experienced teachers. The less experienced teachers were clear that they did not consider the lesson to be geared toward inquiry. Baker stated, "You're just plotting points. They're not discovering anything." Fowler felt similarly when she stated, "This just seems like drill and practice. I mean how do you teach? This is pretty straightforward."

Gilbert began by sharing a similar opinion to the newer teachers. However, after rethinking for a moment, she changed her mind and decided that the lesson did support inquiry. In defense of her answer, she said, "Yeah, it would be inquiry based because they would have to manipulate it in order to make a shape. They're doing something new from taking just coordinates, so 'Yes' because of the manipulation factor."

This activity was originally included because after using it in this classroom, Fowler consulted with her coach before answering the snapshot interview question. After her coach implied that inquiry was present, Fowler agreed and then supported her answer; but it felt rather out of keeping with her previous answers. Revisiting the activity in the task-based interview gave her the opportunity to change her mind, but Fowler echoed her previous response when she said, "I think there's a good question here of, 'How can I do

this? How can I use these ordered pairs to actually create something functional for me?'" She continued to talk about making connections but in a very literal sense rather than figuratively as she added, "They are going to have to think about how it's going to connect…how one pair is going to connect to the other pair."

The teachers' reactions to the 'Is It Inquiry?" portion of the third interview, coupled with observation data and their self-perceptions about their use of inquiry, provide a foundation for the following section where the focus now shifts to constructing each teacher's view of mathematical inquiry.

Shared Features of Mathematical Inquiry

This section addresses the commonalities among the four teachers' views of inquiry-based instruction. The subsequent section emphasizes the uniqueness of their interpretations. Both perspectives contribute to the understanding of mathematical inquiry.

Student Centered

The term 'student centered' was rarely used by the teachers themselves. Instead, the teachers spoke of a fundamental shift in their classrooms when inquiry was taking place. The teachers tended to describe this in terms of what was not happening in their classrooms. For instance, while discussing the Spinner Game, Gilbert said, "They'd come to it [a conclusion] on their own without me telling them, 'Well, this is this and that's why' you know, instead of lecturing to them." When mathematical inquiry was occurring in their classrooms, the four teachers agreed that they were not lecturing or

directly presenting the day's material to their students. In reference to the Volume Formula activity, McClure said, "I did not get up and say, 'Well, guys, today you're going to multiply the base times the height. They figured it out for themselves.'" Speaking more generally of inquiry, Baker added, "You're taking away from necessarily the teacher standing in front of the classroom with the book. You're getting them [the students] to do something in their heads more than just the teacher up there telling them what it is."

Teacher Guided

Instead of seeing themselves as lecturers when encouraging mathematical inquiry in the classroom, the teachers mentioned seeing themselves in the role of a guide or as Fowler termed it, "a facilitator." The teachers identified two primary features of their role as a guide: 1) to encourage perseverance and 2) to scaffold inquiries so they were more accessible, or challenging, for their students. The two roles are not unrelated as the scaffolding provided by the teachers enabled some students to persevere who might not otherwise have been able to do so.

Baker recollected telling her students, "You need to think about it…. Put down your [pencil] answer and then think," in order to encourage them to engage with the Distance from Home problem instead of merely making a random guess or skipping the problem entirely. Gilbert echoed this desire for her students to persist:

> I don't want them where it's so frustrating they give up either, and I've had that. I've had a few kids in here say, "I can't do it. I'm not going to try." I go, "Come on. Push yourself a little bit."

Carefully placed questions or comments helped students engage more fully in inquiries. When asked about the role of teacher questioning in inquiry Fowler said, "That's where the facilitation part comes in a lot and when kids get stumped that's where the teacher questions can help them…to develop even their own questions." Baker also discussed how she could use questioning or comments to scaffold an inquiry for students. She stated,

> Sometimes they need a little spark, especially these kids who are just now getting into inquiry. So I might have to say to them, "Well, did you ever think about this?" I usually say it in the way, "You know, in the other class so and so said it this way," because I don't want to make it sound like it's me. Because then they think, "Oh, peers thought that?"

All four teachers were able to agree that the Volume Formula activity, originally from McClure's classroom, represented guided inquiry as it provided scaffolding for the students which enabled them to proceed further with the activity. After the students had spent the bulk of the class time creating different rectangular boxes and finding their volumes by filling them with cubes, they had difficulty abstracting to the formula for the volume of a rectangular solid. McClure guided the students by placing dimensions and corresponding volumes on the board, but left the students to find the pattern that was present.

During the task-based interview, Fowler and Gilbert both spoke of ways they could use questioning to extend inquiries beyond the original design of a lesson. In the Volume Formula problem, Gilbert suggested adding questions:

> "What if I had a big box and I needed to find out how many could fit in there?"…"How could I do that?"…I think you'd need to take it that step further and use questioning in order to get them to get to that point.

When speaking about the Turtle Plotting activity, Fowler thought she could "further the inquiry to maybe have the turtle rotate. 'How are you going to get it to rotate?' or use some angles, use some transformations, different kinds of things." Similarly, Fowler spoke of how she could ask, "If it's not a fair game, how could you make it a fair game?" in the case of the Spinner Game.

In their third interviews, Gilbert and Baker both spoke of how guided inquiry was the most common form of mathematical inquiry in their classrooms. Baker referred to her guiding role in the mathematics classroom when she said, "I can't just teach full inquiry, I would lose the kids for sure because I would be lost," before adding in a joking tone as if addressing her students, "Today, we learn about shapes and here's all your shapes. Figure out the names for them."

Mentally Active Students

Because the teachers were not dispensing knowledge to the students, the students bore the responsibility of playing a more active role in the classroom. This more active role was fulfilled through the students being mentally active or perhaps just "thinking" about mathematics. Gilbert spoke repeatedly of activities involving inquiry where her students had to "figure it out," as in her discussion of the Volume Formula activity where she said, "I'm not going to take all of these tiny cubes and then fill it all in so they had to figure it out." McClure spoke of how the Spinner Game would require her students to "come up with some sort of mathematical rule or reason." Baker referred to the Park Design problem and how it required her students to "think outside the box."

The teachers felt that engagement would be a natural outcome of the students being mentally active in the classroom. Baker stated, "You can't have [mental] action without being engaged." This link was also clearly articulated by Fowler during the third interview when she said of action, "It can be paper and pencil but it's really linked to engagement….They [the students] are taking action but they're engaged in what they're doing and the action is in their brains. These two [engaged and active] are really tied together." In other words, she felt that physical activity was not required for mathematical inquiry. Gilbert was in agreement when she said, "Action could be anything from using manipulatives, to working something out, to physically standing up and moving or doing something, to even doing figuring on paper."

On the first day of classroom observation, McClure noted that her students had difficulty with the greater expectation of mental activity that had been placed on them by their new textbook. "For the first month," she said, "I kept saying, 'Just think!'" In the past her students had been able to play a passive role in their mathematics class.

Students Building Meaning

The teachers were not always in agreement about what form this knowledge or meaning should take. However, they did agree that the students had to be gleaning something new from an experience in order for it to be an inquiry. For Baker, this particular aspect seemed almost too obvious. She asked, "Why would you do anything if you weren't building meaning?" She felt that every worthwhile classroom activity, whether or not inquiry was involved, would include the building of meaning.

Conversely, it was clear from the interviews that this aspect of building meaning could not be omitted. The teachers routinely classified activities as not being examples of inquiry when they did not feel the students were constructing any new knowledge from the experience. This was the case with all four teachers' assessment of the Place Value Problem. As McClure said, "They're not learning anything from doing it other than how many people go to the state fair, which isn't mathematical."

When talking about the Distance from Home problem, Gilbert noted that solving the problem would have to be a new experience for her students in order for it to be inquiry. "If I'd done several like this then no, it wouldn't be [inquiry]." If students were only using their prior knowledge without gaining any new understanding from the problem, then inquiry was not taking place.

The teachers were not agreed on whether or not new meaning was being constructed in the Toothpick problem. Fowler and McClure felt that the students were not learning anything new from completing the problem since they already knew what equilateral triangles were; therefore, they said that mathematical inquiry was not present. On the other hand, Baker and Gilbert felt the students were building their ability to problem solve. As Baker said, "They have to have a thought process. They can't just do six sticks minus four or something."

Individual Interpretations of Inquiry

While they agreed on several important aspects of mathematical inquiry, the four individual teachers also did expressed unique ideas about inquiry. Some of the most notable distinctions which arose are described in this section. Throughout this section,

Figures 4.3-4.6 provide a visual model interpreting each teacher's view of mathematical inquiry as based on interviews and observations. In every case, the students are at the center of the teacher's view of inquiry; however, the focus or objective that drives the use of mathematical inquiry in the classroom varies between teachers.

Baker's Interpretation

Discovery. Student discovery was the dominant feature of mathematical inquiry for Baker. In her initial overview of inquiry provided at the beginning of her third interview, Baker spoke of inquiry as "discovery and…letting the kids kind of engage in their learning, not just be told." She agreed that the goal of inquiry is for students to construct knowledge, but rather than focusing on arriving at that destination, she emphasized the journey itself and the discoveries made along the way. For instance, during the third interview, she said the act of discovery might be as simple as, "Oh wait a minute, it's not as it seems at first," as the students tackled an activity that lent itself to inquiry. One example of this that she cited was the Distance from Home problem.

Different Levels of Inquiry. Over the course of classroom observations, Baker began to speak more about the existence of different levels of inquiry. She was the only one to explicitly reference varying levels of inquiry although the only two levels that she clearly identified were guided inquiry and what she called full inquiry. As she contemplated inquiry and the Toothpick problem, she stated "I just want to make it clear…my opinion isn't just black and white. I think there's many levels of it and all these in one way or another can be incorporated to make it inquiry." When talking about how to modify the

Place Value task she noted that her modification "may be not full inquiry." In discussing the Park Design task, she first brought up different levels of inquiry and then said,

> I think it's a different kind of inquiry because I attribute inquiry to learning something new and it doesn't have to be. This is an inquiry based on review where they had to take out…concepts that we learned in Chapter 12 instead of doing a test and put it together to create a park.

Making Connections. Baker focused on connections that students could build between the different mathematical ideas in particular inquiries. For instance, in the Part of the Whole activity, she justified it as being an inquiry activity by saying, "They're not just seeing shapes separately. They can see how they are all interrelated." In the case of the Volume Formula activity, she said, "They're taking the concept…an algorithm, length times width times height, and they're actually getting to physically see it…not just being hands on but also interrelating it beyond the numbers." The students were connecting what they saw from the manipulatives with the pattern present between the dimensions and volume of each box, and with the more abstract formula for volume.

In Baker's case, the newly constructed knowledge might also form a connection between formerly disparate ideas. She said, "I'm taking two concepts that I already know and I'm relating them. I think inquiry can be reviewing something and connecting it, like I said, to something you never thought it could be. You know… connecting algebra and geometry."

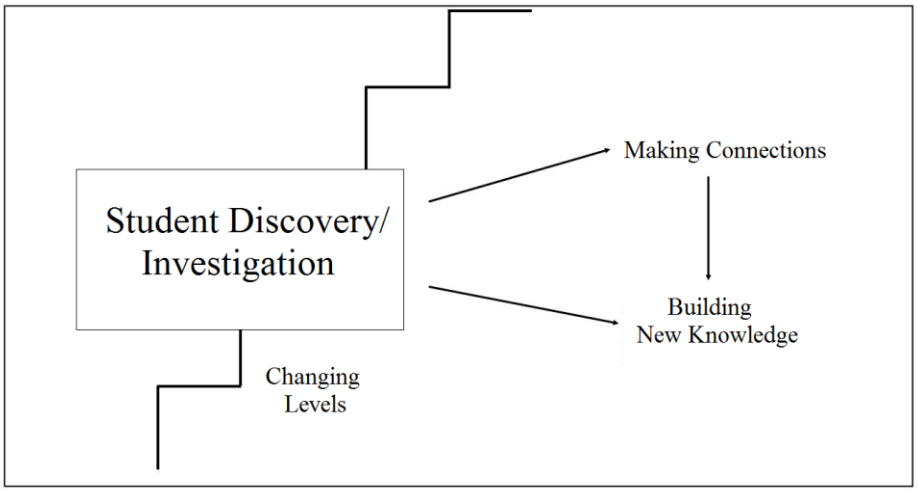


Figure 6. Ms. Baker's Interpretation of Mathematical Inquiry

Fowler's Interpretation

Student Questioning. Student questioning formed the backbone of mathematical inquiry in Fowler's mind. After noting "That's the most important component to me," she elaborated on the topic: "That question can be, 'How am I going to do this?'...but I want to see the kids questioning." Even in her role as facilitator and guide, she felt that the primary reason for her to question students was to help them develop better questioning abilities of their own.

She again noted the importance of questioning on the part of the students when commenting on the Parts of a Whole activity:

> It involves investigation and it involves questioning. "What do I think about this? What do I think is actually going to happen?"…To actually discover if their prediction is correct and then to carry that on to "Does that now make sense?" and then to go even further to "Is it mathematically sound?", you know, to "Will it work in all the cases?" And so you've got a way to test, you know, to discover, go test, to prove what you're doing and…the questioning and the prediction are huge in inquiry.

The Clear Objective. In order to determine whether or not inquiry was present or supported by a particular activity, Fowler would think about the objective of the activity. If she could not find a particular objective that was fulfilled through completing the activity, then she would not classify it as inquiry. For instance, after examining the Parts of a Whole activity, Fowler said, "I think that would be a nice bit of inquiry to discover some fractional parts and the relationship of equivalent fractions that are in there." Knowing what she determined to be the objective of the Parts of a Whole activity, she felt more comfortable classifying it as inquiry. This sentiment was echoed in speaking about the Turtle Plotting activity where she said, "I think there's a good question here of, 'How can I do this? How can I use these ordered pairs to actually create something functional for me?'"

In contrast, when speaking of the Toothpick problem, Fowler said, "I don't know that this is necessarily inquiry. I need an objective here." She also noted for this activity that merely seeing whether or not students could do the problem was not a sufficient objective. At a later point in the interview when discussing the same problem she said, "If I'm going to put it in as an inquiry lesson, I guess I want to know what it is I'm looking for, what the point is. That's all it is." At first the Park Design activity was difficult for her to classify initially because she was not clear as to the objective. However, she eventually determined a sufficient objective: "To say, 'How are we going to do this?' and to question and to discover and to connect to real life."

Discovery. Much like Baker, Fowler noted the importance of discovery in her rapid fire definition of inquiry provided at the beginning of her interview. She identified

inquiry as "student-centered, discovery of concepts or ideas," and mentioned its presence in such places as the Parts of a Whole activity. Unlike Baker, Fowler felt that discovery played a lesser role in inquiry than questioning.

Making Connections. Fowler spoke more of how students needed to be making connections to their real lives at some point during the inquiry. Fowler's desire to emphasize potential real world applications was also evident in classroom observations. Not limited to inquiry-based activities, such connections were made during classroom discussions with the students. In her third interview, Fowler said:

> I love the connections. I think when it becomes everyday then it becomes more important and then the inquiry has purpose for them. I think if they don't really have a lot of purpose in mind or a lot of connection there to their life, I don't think inquiry exists as much and I think it's really huge. That's one reason I try to ask kids, you know, "Where do you see this used? Where could it be used?"

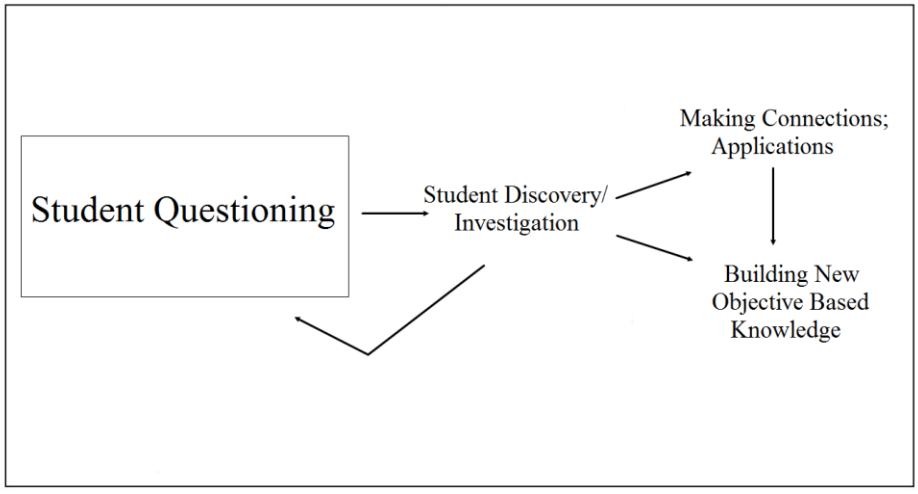


Figure 7. Ms. Fowler's Interpretation of Mathematical Inquiry

Although she initially stated that the Park Design problem was not a source of mathematical inquiry, Fowler changed her mind later in the interview after deciding that the real world connections resulting from the activity made it a good source of inquiry.

Gilbert's Interpretation

Teacher Guided. While already discussed under the shared features of inquiry, the aspect of teacher guidance is included here to highlight the extent to which Gilbert emphasized her role as a guide. When giving a synopsis of what inquiry meant to her, Gilbert said, "and a lot of mine, I think, is guided inquiry where I guide them by giving them a few questions and then through their questioning and through their working things out, they acquire a new knowledge on their own." Gilbert worried that she might provide too much guidance to her students at times which could thereby eliminate the inquiry from the problem.

Making Connections to Prior Knowledge. Like Baker and Fowler, Gilbert felt the forming of connections was an essential feature of inquiry. However, each of the teachers varied in their interpretation of what it meant to make connections. She said, "I think that's how they do it [build knowledge]. They have to connect what their previous knowledge is to their new knowledge to get to the new knowledge." While Gilbert ultimately decided that the Park Design activity was not inquiry because students did not gain sufficient new knowledge, she initially said, "It could be inquiry based in the fact that they had to manipulate their previous knowledge to put a project together." More

than any of the other teachers, Gilbert placed an emphasis on the need for students to base their newly discovered knowledge on the firm foundation of prior knowledge.

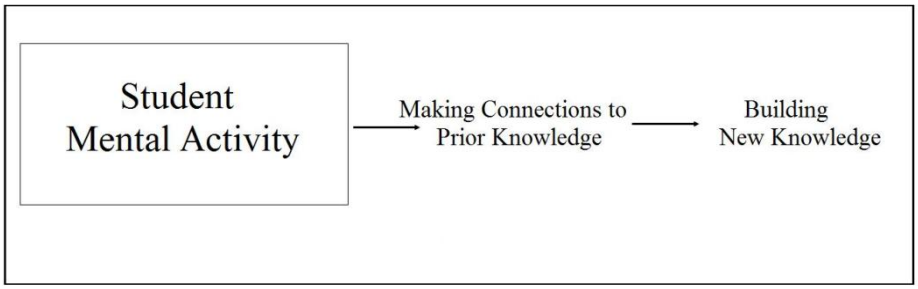


Figure 8. Ms. Gilbert's Interpretation of Mathematical Inquiry

McClure's Interpretation – The Blinding Light of Truth

Of the four teachers, McClure's standard for inquiry was both the most simple and the most difficult to attain: "I think of inquiry as being child-led activities that are building meaning of mathematical concepts and…where they're investigating something and then gleaning some great blinding light of truth from it." This last aspect, the "great blinding light of truth," was of particular note. While investigation and student centeredness were important in her mind, the discovery of some new big mathematical idea, in the form of newly constructed knowledge, was crucial in her opinion.

For example, the Volume Formula activity, derived from a lesson in her classroom, was one of only two items in the interview where she believed that inquiry was present. She said, "This activity I thought was totally inquiry because the kids knew what volume was by the end of it….They figured it out for themselves." Prior to the lesson, the students had never formally learned about the concept of volume in the classroom. After the lesson, students (at least ideally) had built their own models to find

volume and had used their skills at patterning to develop a formula for computing the volumes of other rectangular prisms. Thus, the brand new idea of computing volume was the "blinding light of truth" that the students had discovered.

McClure felt the same about an activity where students discovered how to find the area of parallelograms after cutting out a number of parallelograms and experimenting with cutting them in order to facilitate finding their areas. After that lesson, McClure expressed that she did believe that inquiry was present in that activity. She went on to add, "Every single kid was able to say area equals base times height and that wasn't something that I gave them."

In contrast, McClure did not consider the Parts of a Whole activity to be an example of inquiry even though the students were actively using pattern blocks at their tables and making discoveries such as the notion of equivalent fractions. In her snapshot interview after the lesson, McClure stated, "I don't feel like that was inquiry either because once again it was building on their earlier knowledge." Since a new "big idea" was lacking, McClure did not feel that the activity constituted an example of inquiry. Discussing the activity, McClure stated, "I think this is one of those experiences that they definitely gain things from but I don't know that there was one great mathematical concept that really came out of this activity." She added that the students "constructed meaning from it, but it just wasn't necessarily through inquiry that they were constructing meaning."

McClure repeatedly noted what she saw as a clear distinction between what she called concept building or building meaning and inquiry. After a

classroom lesson where students had to estimate the area of their skin and then set about making more accurate calculations she stated, “A lot of people think you aren't doing inquiry unless you are building concepts. I think I was building concepts but not doing inquiry.” She said the same about a lesson on weight later in the semester where students found classroom items that they felt represented different metric masses such as 1 g or 1 kg. In her mind, students were building new concepts but not discovering new ideas that were significant enough to be considered inquiry.

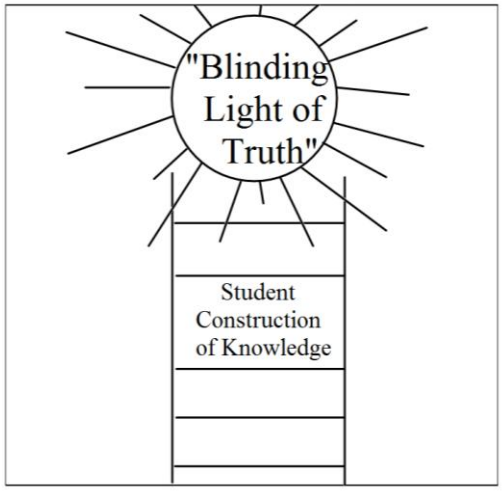


Figure 9. Ms. McClure's Interpretation of Mathematical Inquiry

Unsettled Definitions

Despite their willingness to speak about inquiry, all four of the teachers mentioned at one time or another that their definition of inquiry was not completely static. They also agreed that different people might have different definitions of mathematical inquiry. In discussing her answer to the Turtle Plotting item, Baker said, “Maybe some teachers think differently.” Later, while discussing inquiry in general, she

noted the danger of falling "into the gray area, definitions of words." Gilbert said of inquiry, "I suppose it's something like that where everybody has a little bit of their own idea."

Despite acknowledging that mathematical inquiry could be interpreted differently by different people, Baker and Gilbert both individually asked to know what the "true" definition of inquiry was at the end of their third interviews. Gilbert said, "What the heck does inquiry mean? Are you going to tell me?" Gilbert, in particular, expressed a desire to see how her personal definition compared to a (nonexistent) established definition of mathematical inquiry. At one point in the third interview when particular features of inquiry were being discussed she said, "I'm one of those people that needs reassurance. I want to know if I'm right."

Fowler and Gilbert both changed their answers to items in the "Is It Inquiry?" interview, Fowler on the Park Design activity and Gilbert on the Distance from Home problem. The changes of opinion were not the result of confusion over the activities but rather a result of clarifying their personal interpretations of mathematical inquiry and how the activities fit into those interpretations. After articulating how she believed making real life connections could constitute inquiry, Fowler went back and revised her response to the Park Design activity. Fowler said, "This one [Park Design] I've actually been mulling over in my brain and as you noticed when we went to the next one, I kind of went back to this one and I think this one could have a lot of inquiry in it." Similarly, Gilbert struggled with the amount of guidance that was permissible in the Distance from

Home problem before deciding that it could be used for inquiry with sufficient scaffolding.

Individual interpretations of inquiry were subject to outside influences. For example, when examining the Turtle Plotting activity, Fowler gave a response that was out of character with her previous responses by saying that the activity did include inquiry. As it turned out, she had asked her coach for an opinion before responding; and after her coach responded in the affirmative, she agreed. Fowler may have modified her answer to fit the coach's thinking: her response was somewhat out of character, and the usually articulate Fowler struggled to justify her thinking. However, she did persist in her classification of the Turtle Plotting activity as an inquiry activity, even in her third interview.

Similarly, Baker and her more open definition of inquiry had a tendency to influence Gilbert, who was more hesitant to classify activities as inquiry. As witnessed in observations, the two would talk during the breaks in the middle of their mathematics classes. They engaged in discussions on whether or not inquiry was present on days when students were working on their Park Designs and when students were engaged in logic puzzles. In these cases, Gilbert was uncertain but leaning toward the activities not supporting inquiry. Baker provided her with a convincing argument that inquiry was present although Gilbert did later change her response back to "not inquiry" in the case of the Park Design activity during her third interview.

The teachers noted that their definitions were changing over time. Discussing the Park Design Problem, Fowler said, "Maybe if you'd asked me in February, I'd give a

different answer." Baker described how her understanding of mathematical inquiry had changed over the course of the school year. In her third interview, she said, "I used to think it was more hands-on at the beginning of the year." She also acknowledged that at the beginning of her participation in MGM she believed that students had to be building new knowledge in order for inquiry to be occurring. She said, "I used to think that, but I don't think that anymore…I think inquiry can be reviewing something and connecting it."

Even McClure, who throughout observations had applied a consistent personal definition of mathematical inquiry, noted that her notion of inquiry could be evolving. In her third interview after all classroom observations were completed, she was asked whether the knowledge that her students constructed had to be new knowledge. She responded with, "It could…it has…maybe…either new knowledge or looking at something in a new way. I guess I've never thought of that one."

Summary

In this chapter the findings of this study were presented in relation to the research questions that they addressed. It was determined that teachers in the MGM project viewed the two-week summer institute and school visits from mathematics coaches as the most helpful for implementing mathematical inquiry in their own classrooms. This belief was mirrored in the four case study subjects, two of whom identified the summer institute as being most helpful and two of whom identified their coach as being the most helpful.

The presence of a strong community of teachers and a mathematics coach were identified as influences that had a positive impact on the use of inquiry in the classroom.

In contrast, time (or rather lack thereof), standardized testing, and the mathematics textbooks were identified as factors that could have a negative influence on the usage of inquiry.

Each teacher's implementation and understanding of mathematical inquiry was explored through analysis of data from classroom observations and task-based interviews. It was found that the teachers agreed that classroom mathematical inquiry was student centered but teacher guided, and that the students had to be both mentally active and building meaning. The teachers, however, had different ideas on what it meant to build meaning and on the role making connections played in mathematical inquiry.

CHAPTER 5

DISCUSSION

In this chapter, the results of this study will be discussed along with their implications and suggestions for further research. This chapter is divided into three components: (1) a summary of the background and methodology of this study, (2) a discussion of the findings, and (3) implications of the findings and suggestions for research.

Background

A shift has been occurring in mathematics education over the course of the past few decades as evidenced by the aims of the *Principles and Standards for School Mathematics* (*PSSM*) published by the National Council of Teachers of Mathematics (2000). In order to better enable students to develop a deep understanding of mathematics, classroom teachers have been strongly encouraged to provide their students with opportunities for mathematical inquiry.

Past reform movements with the aim of increasing the level of classroom inquiry have been largely unsuccessful, perhaps in part because reform efforts require teachers to redefine their roles in the classroom and implement new strategies (West, 1990; Knapp & Peterson, 1991). To further compound the problem, teachers who express an interest in teaching by using inquiry or other reform methods may find that they are unequipped to do so. Professional development was identified as an important facet in bridging the gap between teachers' traditional classroom practices and reform based instruction (e.g.

Constantinos, Eliophotou-Menon, & Philippou, 2004; Loucks-Horsley, Hewson, Love, & Stiles, 1998; Borko & Putnam, 1995; Thompson & Zeuli, 1999).

The purpose of this study was to explore the nature of inquiry as it is perceived, experienced, and implemented by teachers. In addition, this research attempted to identify influences that impact teachers' use of inquiry in the classroom. The study followed four teachers who were ongoing participants in a unique professional development experience, the Middle Grades Mathematics (MGM) project. The following questions guided the study:

What are some of the ways that teachers who have experienced inquiry through professional development carry out inquiry-based instruction in the mathematics classroom?

1. In what ways do they operationalize inquiry-based instruction?
2. What influences affect their implementation of inquiry?

The MGM project was a professional development project involving teachers from schools in west central Montana. In July 2007, 24 teachers participated in a two-week immersion in inquiry-based mathematics at a summer institute. The institute emphasized mathematics content and learners' interaction with the content through inquiry-based learning, to help participants develop pedagogical expertise and mathematical confidence. Academic year follow-up focused on development, implementation, and reflection on lessons that incorporated the content of the summer workshops as well as inquiry-based instruction.

Four teachers who had participated in MGM were selected for this case study.

Interesting contrasts existed between the pairs of teachers which suited them for participation in the study. The teachers in Adelaide used *McGraw-Hill Mathematics* (2002), a traditional textbook series, while Brisbane utilized *Everyday Mathematics* (University of Chicago School Mathematics Project, 1997), a standards-based curriculum that incorporated inquiry-oriented activities into the lessons. Another element of contrast was the support system available to each subject. A total of five MGM participants spanning grades 5-8 worked in the rural Adelaide district and taught almost all mathematics classes in those grades, thereby allowing for more of a "team" approach to experimenting with inquiry. In contrast, the subjects in urban Brisbane had only one other MGM participant at each of their schools.

Data collection for this study consisted of three semi-structured interviews conducted throughout Spring 2008 and a series of fourteen classroom observations for each teacher which were made during the same time period. The observations were intended to occur weekly; however, frequent rescheduling on the part of the teachers meant that some weeks resulted in no observations while other weeks included multiple observations of a single teacher. Fieldnotes were taken during each classroom observation and observation protocols were completed immediately afterward. Each classroom observation ended with a brief "snapshot interview" where the teachers commented on the mathematical inquiry that was contained in their lessons. Program data from MGM was also used to supplement findings as deemed appropriate.

All narrative data (field notes, interviews, and written teacher reflections) were coded using the method of constant comparison. Extended interviews were transcribed

before coding. The transcribed data was entered into spreadsheets to aid in sorting and searching for themes. Highlights from observations were also entered into spreadsheets using themes developed through the analysis of the third interview.

Discussion of Findings

In this section, major findings from the study are presented and discussed. The section begins by addressing influences that impacted the teachers' use of inquiry, and finally moves into how they perceived and defined mathematical inquiry in their classrooms.

Implementing Inquiry: Outside Influences

Three factors seemed to significantly influence the extent to which teachers were willing or able to use mathematical inquiry in their classrooms. These factors – textbook, time, and community – are discussed below.

The Textbook. The textbooks used in the various classrooms impacted how mathematics was taught although not entirely in the way that had been initially envisioned. All of the teachers were essentially enacting a new curriculum that school year, whether in the form of a new text or in the form of teaching away from the text. As anticipated, the teachers in Brisbane felt that their new text lent itself to using inquiry in the classroom. The teachers in rural Brisbane felt that their traditional text did not support mathematical inquiry. These attitudes set up an expectation by the researcher that teachers with the standards-based text would be able to use mathematical inquiry in their classrooms and that the teachers with the traditional text would become frustrated

with the limitations of their text and revert to their old ways of teaching. The error in this thinking became clear shortly after observations began.

While the teachers did believe that their textbooks either supported or did not support mathematical inquiry as anticipated, the teachers' attitudes and efforts toward incorporating mathematical inquiry did not follow expectations. In Brisbane which used the reform text, the teachers followed the lessons as laid out in the text. If a lesson happened to incorporate what the teachers saw as inquiry, then they would state in their snapshot interviews that inquiry was present. However, inquiry was not a focus of the classroom, nor were the teachers seen to make efforts to heighten opportunities for inquiry in the classroom. In that sense, the teachers were dependent on their text to provide opportunities for inquiry and, not surprisingly, not all such opportunities resulted in inquiry. Tarr et al. (2006) raised the idea that textbook fidelity might not be in the best interest of the mathematics classroom even when the text happens to be standards based. His finding corresponded with those of this study, which demonstrate that mathematical inquiry is a more involved process than simply opening a workbook.

In contrast, the teachers in Adelaide did not fall back on their traditional text but began to think outside of its confines. They used their coach, outside sources, and each other to design new lessons. They referred to their text as a list of suggestions for organizing topics and for occasional supplemental problems. The teachers were practicing inquiry by investigating their own mathematics teaching, and they created an atmosphere where mathematical inquiry was encouraged on the parts of the students.

What if Adelaide had already begun using a reform text while Brisbane had the

traditional text? Would the Brisbane teachers have been seeking outside opportunities for inquiry? Would the Adelaide teachers have simply followed their texts?

While only speculation, nearly sixty hours of observations provide some basis for prediction. The mathematics classrooms in both districts were impacted by more than just the text. The teachers from Adelaide happened to attend MGM at a time when their school was ripe for change. They left the immersion experience eager to make changes in their classrooms. The energy level and sense of community among the three participating fifth grade teachers (aided by their coach, Dr. Carr) enabled the Adelaide teachers to make changes in their mathematics instruction despite the limitations of their text. With a reform text, it is conceivable that those teachers would have made even more dramatic changes in their mathematics program and usage of classroom inquiry.

In contrast, the Brisbane teachers seemed less motivated to create change and certainly had less support to help affect such change. As such, it is likely that those teachers would have fallen back into their old habits of teaching (albeit with a bit more confidence) after their MGM experience.

Time. All of the teachers were faced with the reality of losing class time to outside activities and to requirements such as standardized testing. In Brisbane, the perceived district expectation that they would proceed through all of the lessons in the book left the teachers with little additional time to delve into a particular inquiry. In Adelaide, the greater freedom and control over the content of daily instruction enabled the teachers to focus on particular topics which they felt were of importance (while eliminating others), which enabled the students to spend more time delving into those topics (often through

inquiry). While the Brisbane teachers felt pressure to get through as much of the text as possible, the Adelaide teachers were able to explore topics more deeply and to cover new topics that they had never had time for in the past.

Community. The influence of community was especially obvious in Adelaide. Despite the challenges posed by their text, the teachers relied on each other, on MGM teachers in higher grades, and on their coach to stay motivated. They were then able to create lasting changes, including the incorporation of more inquiry in their classrooms. While the spark for creating such a community was ignited by the MGM summer institute, the teachers credited their coach with encouraging them to make it a reality.

As they were adapting to the idea of using inquiry in their classrooms, the fifth grade teachers relied heavily on Mr. George, a junior high teacher who had also attended MGM. However, as they gained more experience and confidence, the teachers began developing more of their own ideas and sharing them with one another. As part of their community building, the teachers began routinely meeting to share ideas to use in instruction.

Coaching. The Adelaide coach, Dr. Carr, was identified as a very influential and motivating presence. The teachers from Adelaide identified their MGM coach as the aspect of MGM which helped them the most with implementing inquiry in their classrooms. The teachers spent that school year rethinking which lessons they taught and how they taught them. For them, Dr. Carr, their coach, played a key role in helping to implement those changes. She encouraged them to consider not teaching every lesson in their textbooks and she provided them with outside resources and her own ideas about

how they could teach certain lessons in their classrooms. In addition, she provided them with positive reinforcement which helped them maintain their efforts to change how mathematics was taught at their school.

Other Influences. Other influences were less prevalent but still influential to varying degrees in the use of classroom inquiry. These included standardized testing, manipulatives, and the difference between planned and enacted curriculum.

Implementation of Inquiry: Shared Teacher Perceptions

The teachers agreed that a mathematics classroom that was conducive to mathematical inquiry should be student centered and teacher guided. The students had to be active in the process of building their own knowledge whether that included being physically active (moving about or using manipulatives) or just being mentally active. However, the teachers varied in their interpretations of the knowledge that their students should be building. The essential features of mathematical inquiry that emerged from observations and interviews with the four case study participants are as follows:

Student Centered. Students were no longer passive receptacles of knowledge in the classroom. When mathematical inquiry was occurring, they were responsible for actively participating and doing the work of learning in the classroom.

Teacher Guided. The teachers spoke of changing from their traditional role where they stood at the board delivering a lesson to their students. Instead, after setting up an activity, the teachers would stand back and let the students do the learning. They would

offer words of support and try to ask probing questions in order to further student thinking but attempted to refrain from giving the answers.

Knowledge Building. There was consensus among the teachers that the students had to be building knowledge through the inquiry process. None felt that the element of knowledge building could be omitted from true inquiry. Baker went even further, believing that the purpose of every classroom activity included the construction of knowledge.

Process Oriented. For three of the teachers, the focus of mathematical inquiry was somewhat less on the knowledge that was constructed and more on the student learning process. Baker emphasized the small discoveries (including acknowledging the need for further thought) that students would be making throughout an activity. Gilbert focused on the need for students to be mentally active and engaged in the process and Fowler spoke of her belief that student questioning was the essential component. In contrast, McClure spoke of how students had to see "the blinding light of truth" in order for inquiry to be present in the classroom. While Baker, Fowler, and Gilbert could see inquiry in lessons where students did not arrive at a great mathematical truth, McClure did not believe that inquiry was present unless the final step was accomplished.

Collaborative. Completing work in small groups was not seen to be essential for mathematical inquiry, but it was important for students to be engaged in collaborative discussion, either in small groups or in a whole class setting. While students were sometimes seen to work in groups, group work was neither identified by the teachers as a

key component nor always (or even usually) observed to be present on days when the teachers said that mathematical inquiry had taken place. Whole class discussion, however, was routinely used as a means of building meaning (or clarifying meaning) after either working alone or in groups. Leikin and Rota (2006) also wrote of the increased use of summative discussions in classrooms where teachers were attempting to use inquiry-based instruction.

Implementing Inquiry: Contrasting Perspectives

The list in the last section emphasizes the points of agreement between the teachers. However, the teachers all varied in their individual interpretations. A few contrasts are described in this section.

Polarized Views of Less Experienced Teachers. The two least experienced teachers had both the most open (Baker) and the most difficult to achieve (McClure) notions of inquiry in classroom practice. In Baker's open interpretation, if her students were thinking and achieving small insights into mathematics then they were practicing inquiry. In contrast, by McClure's stricter standard, mathematical inquiry was not present unless the students made a substantial discovery such as the origin of a previously unknown formula.

The two more experienced teachers were less clear cut in their interpretations. They were the ones who were apt to struggle with activities that were more ambiguous in terms of inquiry or even to change their minds. The experienced teachers did not consistently agree or disagree with each other or the other teachers. Teachers with greater experience may show themselves to be more adept at picking up and struggling

with the subtle nuances that contribute to and take away from classroom inquiry whereas teachers with less experience may stick to a simpler system of categorization.

A Unique Case: Ms. McClure. Despite the fact that all observations in Ms. McClure's class were onsite, the researcher spent less time interacting with Ms. McClure when she was not teaching than with any of the other three teachers. As she was the only teacher not to have an interruption in the middle of her mathematics instructional time, informal interviews were unusual in her classroom unlike any of the other classrooms. This does not mean that she was not perceived as being candid in her observations or interviews but rather that opportunities for delving into her understanding were more limited than in the case of the others.

Ms. McClure was only in her second year of teaching at the time of this study. While she and Ms. Baker were both identified for the study because they were less experienced teachers, Ms. McClure was so new to teaching that she was still establishing her practices in the mathematics classroom. In her one year of prior experience, she had been unhappy with how she had taught mathematics. Therefore, in her second year, she arrived with fewer experiences to enhance her teaching with the new curriculum. Not surprisingly, her mathematics classroom was the most traditional and teacher-centered rather than student-centered. Ms. McClure was in a significantly earlier stage of her career and in her development as a mathematics teacher than the other three teachers and it impacted her ability to identify opportunities and seize opportunities for mathematical inquiry.

Although McClure was teaching at a grade level lower than the other cases, the fourth grade curriculum contained lessons that were similar to lessons observed in the fifth grade classrooms. Thus, the fact that she was teaching students who were a year younger was not as essential a difference as the method in which she ran her mathematics lessons.

Of the four teachers in the study, Ms. McClure was the most isolated from other MGM participants. While the other teachers had fellow MGM teachers in their own grade level at their school, the other MGM participant at Ms. McClure's school was a fifth grade teacher not a fellow fourth grade teacher. There was another fourth grade teacher down the hall at her school but they did not talk with each other about mathematics instruction. She did meet with the other fourth grade teacher every week, but those meetings focused more on keeping pace with one another than on the content of instruction itself.

Understanding and Implementation of Inquiry: Its Varying Nature

While the four teachers in this study had all participated in the same professional development experience, they left with differing notions of mathematical inquiry and used it differently in their classrooms. Considerable efforts were made to draw out the similarities among the teachers' understanding and use of inquiry, but the reality was that inquiry looked different in each of the classrooms. Much as Remillard and Bryans (2004) found, the teachers took their common professional development experience and both internalized and implemented it in a manner that differed even between teachers in adjoining classrooms at the same school.

Future Directions for Research

Possible directions for future research are presented in this section. The current reform effort calls for classrooms which are more student centered and which provide students with opportunities to build their own knowledge through means such as mathematical inquiry. While this study has shed light on the these four teachers' perceptions of mathematical inquiry, more work remains to be done in order to better support teachers as they endeavor to implement inquiry with only a limited exposure to the process. Professional developers can only provide this support when they also possess a more complete understanding of mathematical inquiry and its use in classroom practice.

Identify Lasting Effects of Inquiry-Focused Professional Development

This study took place in the midst of a 12-month professional development experience. The four teachers in this study had all participated in the two week MGM institute over the summer prior to this study. During the study, they were receiving ongoing support from MGM in the form of one-on-one coaching and curricular advising. They were scheduled to attend another week-long institute in the following summer. Certainly, observing such classrooms three years or even five years after the teachers had participated in a program would be informative in terms of the depth, longevity and potential growth of inquiry in their classrooms. Would the teachers' implementation of inquiry have evolved since the time of the study? Would mathematical inquiry remain in the minds of the teachers at all?

Examine Influence of Curriculum Comfort Level on Inquiry

The two teachers in Brisbane were in their first year of teaching with the standards-based *Everyday Mathematics* curriculum. Observing teachers who had been using a reform curriculum for more than a year, when the teachers were more comfortable with the material in the book, could give more insight into how such teachers understand and try to utilize inquiry in their classrooms. Ms. McClure and Ms. Fowler had both settled into using *Everyday Mathematics* by the time of the study but did not appear to be comfortable enough with the material yet to deviate from it or to anticipate the areas where their students would struggle. They did not seem to routinely think how they could slightly modify their instruction to incorporate additional inquiry. However, it was not possible to tell entirely whether such practices would continue in future years of teaching from this text or if they were a result of trusting the curriculum for the first year of instruction.

Similarly, the teachers in Adelaide were switching from a traditional mathematics text to a reform based one. While the teachers had fostered an atmosphere of inquiry in their own teaching of mathematics during the time when this study took place, the question arises as to whether this atmosphere will endure in following years. Looking back in their classrooms a few years later could help illuminate whether the atmosphere of inquiry endured or whether the teachers reverted back to teaching from their books – albeit from books that they felt better supported the use of inquiry.

Further Study of Curriculum Influences on Inquiry

While the curriculum emerged as a key influence on the use of mathematical inquiry in this study, the study was not specifically designed to study this influence. Further study should be done to produce more generalizable results on how inquiry occurs in different curricular environments such as a reform versus a traditional environment or a rigidly paced versus a flexible environment.

Explore Perceptions of Mathematical Inquiry in Other Populations

Four teachers' understandings of mathematical inquiry were examined in this study. Parts of the third interview could be taken and used to interview pre-service teachers, mathematics educators, and mathematicians to examine their understanding of mathematical inquiry. In addition, experts in mathematical inquiry could be identified and interviewed for their opinions. As the four teachers in this study did not always agree with one another, a variety of opinions would be expected to result and could help to elucidate the essential qualities of mathematical inquiry and to help establish whether certain features were considered more essential to one group or another.

Examine How Teachers Conclude Inquiry Lessons in the Classroom

In Brisbane, the teachers were seen to bring inquiry lessons to an artificial conclusion. In her lesson on triangles, Fowler quickly brought the students back on track and resolved the debate once the students began to diverge in their thinking. Similarly, Fowler and McClure were both seen to quickly wrap up their lessons as soon as just a few students had reached the desired conclusion. The teachers seemed to be shutting down the inquiry process prematurely for many of their students. Studying how inquiry

lessons are brought to closure could help identify practical strategies for teachers at a critical point in the inquiry process.

Formalize the Observation Process for Inquiry

Further research needs to done to design or modify a classroom observation protocol for use in objectively identifying mathematical inquiry. From there, the teachers' own perceptions of inquiry could be compared with what is objectively observed in their classrooms and in their lessons. This was attempted to a limited extent in this study but was hindered by the limitations previously identified in the protocol and by the need for an established definition of inquiry to use as a frame of reference.

Closely Examine the Impact of the Mathematics Coach

The Adelaide teachers credited their coach, Dr. Carr, with providing the most help in implementing inquiry-based instruction in their classrooms. Dr. Carr was unique among the coaches in that she had a lengthy career as a K-12 teacher as well as an EdD in Education. The other coaches were either K-12 teachers or mathematics educators at a university. In addition, Dr. Carr spent more time with the teachers in Adelaide than the other coaches spent meeting with other individual teachers from the MGM project. In addition to observing lessons and providing general feedback, she helped the teachers plan for those lessons and engaged them in discussions on how to modify lessons that would be continuing after she left. She also provided the teachers with research articles and curriculum materials that she thought would be of interest to them. Dr. Carr developed into what the Adelaide teachers saw as a trusted and invaluable resource for the teachers in Adelaide but it cannot be stated with certainty whether this was due to the

extra time she spent with them, the quality of the information she gave them, her unique qualifications, or even whether it was due to a fortuitous meshing of personalities. Further study is needed into exactly which contributions from coaches have the most influence on the teachers with whom they are working so that mathematics coaching can be developed into a more powerful experience for others.

Recommendations for Educators

This study was originally designed with the intention of producing results that could be useful to both professional developers and classroom teachers. However, results which are useful for one group are not necessarily pertinent to the other. Therefore, this section of recommendations is divided into two parts, one for professional developers and the other for classroom teachers.

For Professional Developers

This section contains suggestions for professional developers endeavoring to support teachers in using mathematical inquiry in their classrooms. Regardless of how they internalize mathematical inquiry, teachers need help in operationalizing their professional development experiences in their own classrooms.

Provide Immersion Experiences for Teachers. The four teachers all spoke highly of their experiences at the summer institute where they learned geometry and algebra through inquiry. The teachers were uncomfortable with the new style of building knowledge at first, but their discomfort with playing a more active role in their own learning has been identified as typical by researchers such as Herbel-Eisenmann (2009).

After working through their initial discomfort in the safety of the institute, the teachers claimed they had been able to develop a deeper understanding of the mathematics they learned.

Develop Teachers' Understanding of How to Implement Inquiry. During the Summer institute of 2007, the participant teachers learned mathematics content through inquiry. Through the experience, the teachers bought into the idea of using inquiry in their classrooms. However, the teachers were not formally instructed on methods for utilizing inquiry with their students. Instead, the teachers were supposed to have picked up strategies for use in their own classrooms at the same time they were learning the mathematics itself. The teachers did identify aspects such as allowing students to work in groups and giving them more time to explore. However, the teachers remained concerned about the prospect of designing or modifying lessons to incorporate inquiry and in facilitating the inquiry among the students. While these issues were largely dealt with during coaching visits, broaching the topics before teachers returned to their own classrooms could have increased both their confidence and abilities in using mathematical inquiry with their students. In particular, teachers could have practiced designing or modifying lessons to incorporate inquiry. In addition, whether from classroom videos or reflection on an activity that they had just completed themselves, teachers could have discussions identifying strategies employed by the facilitator to enhance the students' inquiry.

Ongoing Coaching Visits of Extended Frequency and Duration. In a coaching report filed by Dr. Carr regarding her experiences in Adelaide, Dr. Carr spoke of how she

felt that it was a challenge for her to fully understand the individual mathematics classrooms because lessons were developed over a series of days while she was only present for a short while. Yet, she spent more time in the MGM teachers' classrooms than any of the other coaches. Each quarter, the teachers in Brisbane met with their coaches for observation of a single lesson followed immediately by a short discussion – all of which took less than two hours. All four of the teachers in the case study wanted more time to work with their coaches in order to generate ideas for improving lessons whether in advance or after the fact.

Facilitate Collaboration Among Teachers. The teachers in Adelaide left the summer institute with good intentions of meeting regularly with one another to talk about mathematics. At first, those intentions, victims of the daily pressures of teaching, fell largely to the wayside. The teachers credited Dr. Carr for her efforts to make their good intentions a reality. She pushed them to schedule weekly meetings to discuss their teaching and to facilitate other meetings as issues arose. Those meetings were critical for the teachers who were endeavoring to change from teaching mathematics in a very traditional manner to one that was more standards based especially since the change was attempted without an existing bank of supporting curriculum materials. Such collaboration could be supported within a single school and also between schools in an effort to maximize the exchange of ideas.

For Classroom Teachers

This section presents a list of suggestions for teachers interested in implementing mathematical inquiry in their classrooms.

Collaborate and Share Ideas with Other Teachers. While this issue was addressed under recommendations for professional developers, the benefits of collaboration are for teachers and are, therefore, mentioned here as well. The work of the teachers in Adelaide was made less burdensome through their collaboration with each other and with their coach. While Ms. Baker referred to the changes they were attempting to make as "reinventing the wheel" due to their scope, Ms. Baker and Ms. Gilbert felt such changes were feasible because the three fifth grade teachers were providing support to each other in addition to the support they received from Dr. Carr and other teachers from the school such as Mr. George. The teachers worked together to develop lessons and also to decide which topics to cover. Whether they taught lessons independently that they had developed together, whether they taught a lesson together, or whether they were each teaching their own lesson in a rotation through the others' classes, the three fifth grade teachers in Adelaide were actively involved in supporting each other in the mathematics classroom.

Ensure That Not Just a Few Students are Building Meaning. In multiple instances throughout the observations including area of triangles and volumes of prisms, the students in different classes reached a point in the inquiry where they had great difficulty in continuing. In order to keep the lesson progressing, the teachers asked the students if anyone had made any conclusions. Inevitably, one student had reached the desired conclusion. This student would share his or her conclusion, the teacher would write it on the board as a fact, and the class would then try to use that knowledge to solve additional problems. However, it was apparent that the majority of the class had yet to understand

the big conclusion on the board. Since different students will make discoveries at different times, students will inevitably have some discoveries made for them by their peers. However, those same students still need time to internalize the discoveries through reflection and discussion so that the so called discoveries are not relegated to the realm of random facts.

Encourage "Moments of Inquiry." All four teachers had days with inquiry lessons that encompassed the entire day; such lessons tended to be time intensive both in preparation and in completion and therefore were not feasible for daily use. However, Ms. Baker, Ms. Fowler, and Ms. Gilbert each had days wherein they identified short instances of mathematical inquiry. These three teachers did not necessarily agree on what constituted a "moment of inquiry" due to their differing definitions, but that was less important than the fact that the teachers were recognizing what they saw as inquiry in their own classroom and were fostering it. Such smaller moments made inquiry feasible on some days where teachers did not feel the larger lesson lent itself to inquiry. Opportunities for inquiry varied on a daily basis depending on the lesson and the students themselves; however, inquiry did not occur in these classrooms like an on/off switch where it was either present or not. Instead, it occurred on more of a continuum where the degree and amount of time dedicated to the inquiry varied with the opportunities that arose.

Be Flexible. Teachers should make plans for the day, but also plan for the plans to go awry as they may be guiding their classes through uncharted territory. The observations in this study revealed that inquiry lessons did not always go as planned. In fact, they did

not usually go as planned. In some cases, such as the day that Ms. Fowler's students were investigating how to find the area of triangles, students will become stuck at a key point in the lesson and fail to pick up on even the most carefully laid hints or questions. In other instances, such as Ms. Fowler's lesson on identifying the base and height of triangles, students might begin to engage in mathematical inquiry even when it had not been originally planned. Both situations require flexibility on the part of the teacher to be able to adapt to the needs of the student. In part because different students will find inquiry in different places, pursue it in different ways, and have difficulty in different places, teachers should not expect themselves to serve as perfect guides. No lesson containing inquiry in this study went perfectly smoothly. Instead, the teachers tried their best to adjust as needed and learn for the next time.

Practice Inquiry Into Teaching. Make plans for using inquiry in the classroom, follow through on those plans, and then reflect on how the lesson played out in order to make modifications whether for the future use of that particular lesson or for future lessons in general. Minor modifications in questioning or the structure of lessons can be made over time to facilitate inquiry. Because of the need for flexibility described in the previous section, teachers can benefit from delving into and refining their own usage of inquiry in the classroom.

Create Time Through Alignment to Standards. While some teachers might be limited in their ability to modify the topics they teach, if possible, teachers should considering aligning their instruction to state and/or district standards in order to eliminate the duplication of material in multiple grades and to enable students to learn

required topics in greater depth. Inquiry can be incorporated relatively easily as an effective means of deepening students' understanding of essential topics.

Conclusion

The four teachers in this case study showed that they had distinctly different interpretations of mathematical inquiry. From their different interpretations, a number of consistent features of inquiry were identified. Mathematical inquiry was found to be a student-centered but teacher-guided experience where students built mathematical meaning and collaborated with one another to hone their ideas.

Despite their differing interpretations, all of the teachers acknowledged incorporating mathematical inquiry into their teaching after participating in inquiry-based professional development. While the use of a reform text presented teachers with more lessons that they felt could easily incorporate mathematical inquiry, the teachers that used a standard text were able to incorporate more mathematical inquiry into their lessons through designing lessons of their own or modifying lessons from outside sources.

A clear definition of mathematical inquiry remains elusive. Because of this, the implementation of inquiry in mathematics is difficult to pinpoint. This research study has begun to illuminate some of the commonalities and distinctive features that characterize inquiry in mathematics teaching and learning. The hope is that others will continue to build on the findings of this study to further map the contours of what it means to approach mathematics from an inquiry-based perspective.

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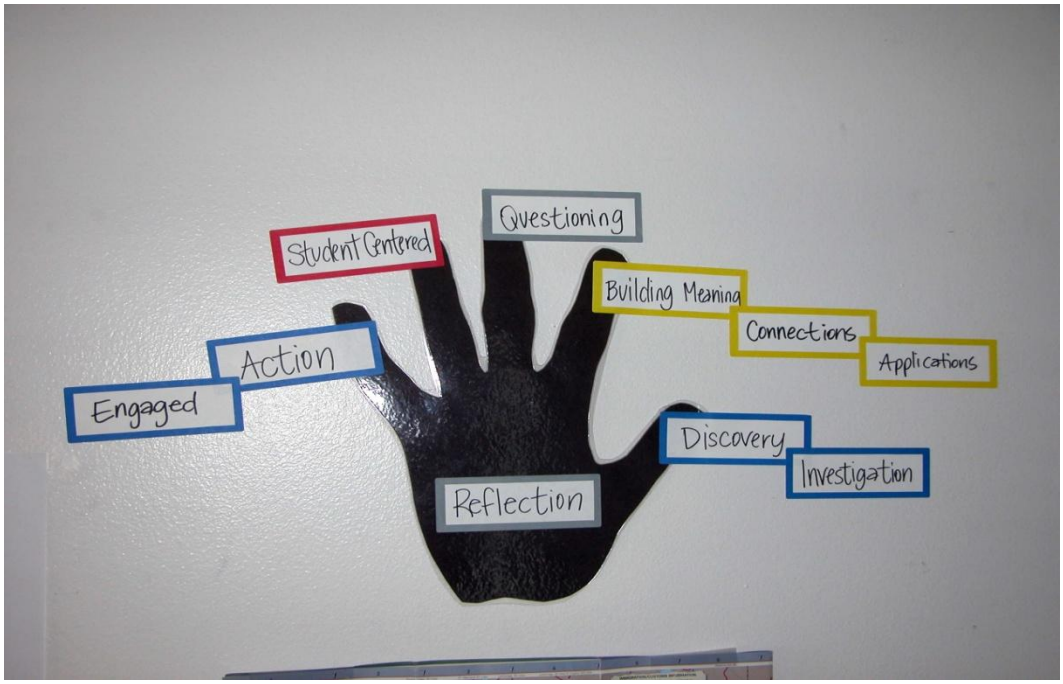
APPENDICES

APPENDIX A

INQUIRY DEFINITIONS FROM MGM PROJECT

TEACHER GENERATED DEFINITION OF INQUIRY

The picture below shows characteristics associated with inquiry at identified by MGM teachers as a group at the Spring 2007 introductory meeting.



INQUIRY DEFINITIONS FROM MGM SPRING 2007 INTRODUCTORY SESSION

These pages were given to teachers as a reference.

What is Inquiry? What is Discovery?

Just what is it exactly that mathematicians do when they are **doing mathematics**? Most people have some sense, however inaccurate in detail, of what different occupations are because they encounter them personally or indirectly through books, movies, and television. They have little opportunity, however, to watch mathematicians at work or to have them explain what they do. Learning how to solve certain kinds of well-defined mathematics problems is important for students but does not automatically lead them to a broad understanding of how mathematical investigations are carried out.

Mathematics can be characterized as a cycle of investigation that is intended to lead to the development of valid mathematical ideas. That is the approach taken in Science for All Americans and in this section of Benchmarks....It is essential to keep in mind that mathematical discovery is no more the result of some rigid set of steps than is discovery in science. It is true that mathematical investigations sooner or later involve certain processes, but the order is not fixed and the emphasis placed on each process varies greatly. Each of the three parts of the cycle-**representation, manipulation, and validation**-should be studied in its own right as part of what constitutes learning mathematics. Students should have the chance to use the entire cycle in carrying out their own mathematical investigations. The purpose of this experience is to produce not professional mathematicians but adults who are familiar with mathematical inquiry.

Each part of the cycle poses some learning difficulties. The process of representing something by a symbol or expression is taken by many students to refer only to "real things." "Let A stand for the area of the floor in this room" is easier for young students to grasp than "Let Y equal the area of any rectangle." First, students have to be convinced that substituting abstract symbols for actual quantities is worth the effort. Then they need to work their way toward the realization that using symbols to represent abstractions, and abstractions of abstractions, also pays off in solving problems. Perhaps this means bringing students to see that in the world of mathematics, numbers, shapes, operations, symbols, and symbols that summarize sets of symbols are as "real" as blocks, cows, and dollars.

As to manipulation, there are two conditions that may seem contradictory to students. One is that there is always a set of rules that must be strictly adhered to; the other is that the rules can be made up. **That is where the rigor and game-playing spirit of mathematics meet.** Imagine some quantities, assign them properties, select some operations, represent everything by symbols, set a problem, and then, following the rules of logic that have been adopted, move the symbols around to see what solutions emerge.

But how good are the solutions? It depends-and that is what students may have trouble understanding. They are used to working mathematical problems in which the procedures are predetermined and "correct" answers are expected. But in real mathematical investigations, a good solution is one that results in new mathematical discoveries or that leads to practical outcomes in science, medicine, engineering, business, or elsewhere. **Thus validation in mathematics is a matter of judgment, not authority.** And where a solution is less than satisfactory, it may have as much to do with the sense of what is good enough or with how the problem was formulated as with how it was carried out.

Project 2061 Benchmarks, from http://www.project2061.org/publications/bsl/online/ch2/ch2.htm#C

Discovery learning is a method of indirect instruction. The teacher structures the learning environment, enabling the learner to develop conclusions....There are various types of discovery learning. **Pure discovery** is defined as learning with no prompts, guidelines, or directions. **Guided discovery** occurs when specific questions are asked, intended to lead the learner in a particular direction toward a desired conclusion. **Open-ended discovery** begins with prompts to start the learner toward one of several possible conclusions. The learner selects the most desirable route and conclusion based on information, opinions, background, knowledge, and thought flexibility....The important thing is not discovery type identification, but that the opportunity to discover is available in the mathematics classroom.

Brumbaugh, D.K. & Rock, D. (2006). *Teaching Secondary Mathematics (3rd ed.).* Mahwah, NJ: Lawrence Erlbaum.

What is Inquiry? What is Discovery?

Teaching by inquiry, discovery, guided discovery, and the Socratic method are frequently used interchangeably for the teaching pedagogy that emphasizes the teacher as guide....Bruner (1966) and Davis (1966) used the term *discovery* or *guided discovery* to indicate **learning of a process rather than the attainment of specific knowledge**....Inquiry-discovery lessons can be either inductive or deductive, and sometimes are even discussed under the headings of inductive teaching and deductive teaching. The **inductive method** is an inference moving from specific examples to a generalization. Since an as yet unexamined case may disprove the generalization, the inductive conclusion must be qualified by some phrase such as "probably" or "it seems reasonable." The main point is for the student to connect common elements in a set of examples and make an abstraction based on that observation. The **deductive method** relies on presentation of certain principles from which students are to draw implications. Thus, the students make logical deductions from prior knowledge.

Considerations when using discovery methods (Cooney and Davis, 1975):

- Have the generalizations clearly in mind
  - Also be open to student-generated methods
- Consider relevant factors before proceeding
  - Is the material appropriate for inquiry? Is it too difficult or involved?
- Plan the sequence of exploration activities or questions carefully
  - Leave gaps the students can bridge without getting lost
- Reinforce the discovery by application
  - Use the generalizations in some meaningful way

Huetinck, L. & Munshin, S.N. (2000). Teaching Mathematics for the 21st Century: Methods and Activities for Grades 6-12. Upper Saddle River, NH: Prentice-Hall

Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work.

Inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations.

Conducting hands-on science activities does not guarantee inquiry, nor is reading about science incompatible with inquiry.

National Science Education Standards, NRC (1996), p. 23.

By the end of 8th grade, students should know that:

- Mathematicians often represent things with abstract ideas, such as numbers or perfectly straight lines, and then work with those ideas alone.
- When mathematicians use logical rules to work with representations of things, the results may or may not be valid for the things themselves.

By the end of 12th grade, students should know that:

- Some work in mathematics is much like a game mathematicians choose an interesting set of rules and then play according to those rules to see what can happen.
- Much of the work of mathematicians involves a modeling cycle, which consists of three steps: (1) using abstractions to represent things or ideas, (2) manipulating the abstractions according to some logical rules, and (3) checking how well the results match the original things or ideas.

Science NetLinks is part of the Thinkfinity, a partnership between the Verizon Foundation and eight premier educational organizations. Retrieved from http://www.sciencenetlinks.com/benchmark_index.htm

HANDOUT OF INQUIRY DEFINITIONS FROM MGM 2008 SUMMER INSTITUTE

This page was given to teachers as a reference.

Inquiry and Discovery Learning

Middle Grades Mathematics Project 2007-2008

Inquiry is a multifaceted activity that involves:

- making observations;
- posing questions;
- examining books and other sources of information to see what is already known;
- planning investigations;
- reviewing what is already known in light of experimental evidence;
- using tools to gather, analyze, and interpret data; proposing answers; explanations, and predictions; and
- communicating the results.

Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations.

Conducting hands-on [mathematics] activities does not guarantee inquiry, nor is reading about [mathematics] incompatible with inquiry.

National Science Education Standards, NRC (1996), p. 23.

Discovery learning is a method of indirect instruction. The teacher structures the learning environment, enabling the learner to develop conclusions.
Guided discovery occurs when specific questions are asked, intended to lead the learner in a particular direction toward a desired conclusion.
Open-ended discovery begins with prompts to start the learner toward one of several possible conclusions. The learner selects the most desirable route and conclusion based on information, opinions, background, knowledge, and thought flexibility.
Pure discovery is defined as learning with no prompts, guidelines, or directions.

Brumbaugh, D.K. & Rock, D. (2006). Teaching Secondary Mathematics (3rd ed.). Mahwah, NJ: Lawrence Erlbaum.

APPENDIX B

CONSENT FORMS/TEACHER EXPECTATIONS

LETTER TO PRINCIPALS

Middle Grade Mathematics Project

January 15, 2007

Dear [Insert Name Here],

I am a doctoral student in mathematics education at Montana State University and am currently in the early stages of my dissertation on inquiry teaching in the mathematics classroom. In general terms, inquiry is being used when students are actively delving into mathematics, asking questions, seeking to answer their own questions, and perhaps using manipulatives or experimentation in their investigations. However, in practice, the operational definition of inquiry (how the teachers actually use it in the classroom) varies greatly from classroom to classroom.

I am seeking to regularly visit the classrooms of [Insert Teacher's Name] and [Insert Second Teacher's Name] in order to gain insight into what inquiry looks like in their classrooms. I am not seeking to somehow grade or score their use of inquiry. Instead, the hope is to gain a better understanding of how inquiry translates into classroom practice.

To that end, I will be collecting data in the following ways from these teachers:

- Weekly observations of mathematics lessons (alternating between visiting in person and using videotape)
- Brief snapshot interviews after lessons and more extended interviews every three weeks
- Journal entries made every other week by the teachers
- Classroom documents such as lesson plans or worksheets
- Program data from the Middle Grades Mathematics Project

Please note that while I will be collecting a considerable amount of information, the only two methods that would require a time commitment on the part of the teachers are the journal and the interviews. My intent is to minimize the burden that I place on [Insert Teacher Names]. They will not have to plan special lessons for my visits. On days when I do visit, I will strive to interrupt the flow of the classroom as little as possible. I will arrive and leave at times that are convenient to the teachers and will attempt to be as unobtrusive as possible.

I appreciate your willingness to consider letting me into [Insert Teacher Names]'s classrooms. Should you consent to my presence in your school, you may still contact me at any time with any comments, questions, or concerns that you might have. I can be reached at (xxx) xxx-xxxx or via E-mail at xxxxxxxxx.

Sincerely,

Heather Mathison

Subject Consent Form For Participation
In Human Research at Montana State University

Project Title: Implementing Professional Development: A Case Study of Mathematics Teachers Using Inquiry in the Classroom Context.

You are being asked to participate in a case study of the use of mathematical inquiry. This research is being done as part of a dissertation study by a doctoral student in mathematics education. This research may help math educators to better understand how inquiry is used in different mathematics classrooms. As a participant in the Middle Grades Mathematics Project (MGM), you have been identified as a possible candidate for this study.

I. If you agree to participate, you will be asked to permit the following data collection activities in your classroom during the 2007-2008 school year:

- An initial interview to collect background information with follow-up interviews
- Weekly observations of mathematics lessons in your classrooms
- Informal interviews following observations
- Allowing access to materials from coaching sessions
- The collection of relevant classroom documents (e.g. handouts or lesson plans).
- A brief journal (responding to specific prompts) regarding your perceptions of inquiry in your classroom. Excerpts may be quoted in my research findings.

II. As part of the classroom observations, I would like to periodically videotape your math lessons in order to more closely examine inquiry in your classroom. Ideally, I would like to arrange to tape a math lesson every two weeks. Other than myself, the only potential viewers of these tapes would be yourself and my adviser (Your coach will <u>not</u> have access). The tapes will otherwise be kept confidential. They will be stored in a locked cabinet and will be destroyed at the end of this study. Part of the lessons from the videotapes may be quoted in my research findings. Any quoted material will be kept anonymous.

Students will not appear on the tapes or be quoted without the approval of a parent or guardian. I will ask you to distribute a consent form for guardian approval. In reporting the findings of this study, details about you, your students, and your school will be kept strictly confidential, and any identifying information will be kept out of future publications.

Any additional questions about your rights as a participant in a research study and be answered by the Chair of the Human Subjects Committee, Mark Quinn, (xxx-xxx-xxxx).

Authorization: I have read the above and understand the various requests being made.
I, _____(*print your name*), agree to participate in the project as described above.

Specifically (your initials in each blank indicate your agreement):

I. _____ I agree to the general data collection from my classroom as described during Academic Year 2007-2008 for purposes of this study.

II. ____ I will permit classroom videotape(s) to be used for analysis and possibly quoted. I understand that no identifying information will be given about me, my students, or my school.

I understand that I may later refuse to participate, and that I may withdraw from the study at any time. I have received a copy of this consent form for my own records.

Signed:_____ Date: _____

Witness: _____ Date: _____

Investigator: _____ Date: _____

Any Questions?

Contact Heather Mathison
xxxxxxxxxx@xxxxx.edu or (xxx) xxx-xxxx

Subject Consent Form For Participation in Human Research
At Montana State University

Project Title: Implementing Professional Development: A Case Study of Mathematics Teachers Using Inquiry in the Classroom Context

Your child's teacher is being asked to participate in a study of inquiry teaching. This research is part of a dissertation study by a doctoral student in mathematics education. This study may help educators better understand how inquiry is used in the classroom. Your child's teacher has already agreed to participate in this study. In order to more deeply understand her instructional practices, I would like to videotape a number of mathematics lessons in her classroom. The videotaping will take place in the late winter and spring of this school year (2007-2008). My primary interest is in [Insert Teacher's Name]'s actions; however, your child may be videotaped in the course of ordinary classroom events. I will use the tape to identify and analyze episodes of inquiry learning in[Insert Teacher's Name]'s classroom. As part of reporting my findings, I may provide quotes from lessons that include your child's responses.

The risks to children who participate in this project are minimal. No one will view the videotapes except for myself and my adviser. The videotapes will otherwise be kept confidential. They will be stored in a locked cabinet and destroyed upon completion of this project. Should your child be quoted, it will be done in the context of a classroom discussion and completely anonymous. Your child's participation is in no way related to the grade he/she will earn in class.

Any additional questions about the rights of human subjects in a research study can be answered by the Chair of the Human Subjects Committee, Mark Quinn (xxx-xxx-xxxx).

Authorization: I have read the above and understand the nature of this project.

I, _____ *(name of parent/guardian)*, related to the child as _____

(relationship), agree to the participation of _____ *(child's name)* in this research. I understand that my child or I may later refuse to participate and that my child (through my action or his/her own action) may withdraw from this research at any time. I received a copy of this consent form for my own records.

To indicate your agreement, initial the following:

_____I understand that my child's classroom responses may be quoted anonymously in the context of classroom discussion.

_____ I understand that my child's image may appear on videotape as part of data collection on inquiry teaching.

Signed: _____ Date: _____

Witness: _____ Date: _____

Investigator: _____ Date: _____

Any Questions?
Contact Heather Mathison, PhD Candidate, Mathematics Education,
xxxxxxxxxx@xxxxx.edu or (xxx) xxx-xxxx.

TEACHER EXPECTATIONS

Duration of overall commitment: January thru May of 2008		
General Aspects of itment	Specifics	Time Involved
Classroom Observation	Permit an Observer RTOP Protocol Videotaping	Weekly Weekly Bi-Weekly or Less
Access to Materials	Classroom Documents Coaching Documents	Occasional Infrequently
Journal	Reflection on one episode of inquiry	Weekly
Interviews	Initial Background Reflective Interviews Informal Follow-up	60-90 min. in January Twice; 30-60 min. each 5 min., Weekly

APPENDIX C

OBSERVATION PROTOCOL

OBSERVATION PROTOCOL

Likert scale items on this protocol are selected items from the Reformed Teaching Observation Protocol (RTOP).

The instructional strategies and activities respected students' prior knowledge and the preconceptions inherent therein.

1 2 3 4 5

The lesson was designed to engage students as members of a learning community

1 2 3 4 5

-In this lesson, student exploration preceded formal presentation.

1 2 3 4 5

-This lesson encouraged students to seek and value alternative modes of investigation or of problem solving.

1 2 3 4 5

The focus and direction of the lesson was often determined by ideas originating with students.

1 2 3 4 5

-Students used a variety of means (models, drawings, graphs, concrete materials, manipulatives, etc.) to represent phenomena.

1 2 3 4 5

-Students made predictions, estimations, and/or hypotheses and devised means for testing them.

1 2 3 4 5

-Students were actively engaged in thought-provoking activity that often involved the critical assessment of procedures.

1 2 3 4 5

-Students were reflective about their thinking.

1 2 3 4 5

Intellectual rigor, constructive criticism, and the challenging of ideas were valued.

1 2 3 4 5

Students were involved in the communication of their ideas to others using a variety of means and media.

1 2 3 4 5

Considering the *constructional time* of the lesson, approximately what percent of this time was spent in each of the following arrangements?

Whole Class _____%

Pairs/small Groups _____%

Individuals _____%

100

APPENDIX D

OBSERVATION OVERVIEWS

Teachers' Composite Scores on Observation Protocol

	Mean				Median			
	B	**F**	**G**	**M**	**B**	**F**	**G**	**M**
Scored: 1-5 1 Low, 5 High								
The instructional strategies respected students' prior knowledge and the preconceptions inherent therein	4.64	4.50	4.57	4.21	5.00	5.00	5.00	5.00
The lesson was designed to engage students as members of a learning community	4.07	4.29	3.29	2.86	4.00	4.50	4.00	2.50
In this lesson, student exploration preceded formal presentation	3.43	3.64	2.93	3.57	4.00	4.50	3.00	4.00
This lesson encouraged students to seek and value alternative modes of investigation or of problem solving	3.00	2.79	2.07	2.00	2.50	3.00	1.00	1.00
The focus and direction of the lesson was often determined by ideas originating with students	2.00	1.57	1.86	1.14	1.00	1.00	1.00	1.00
Students used a variety of means (models, drawings, graphs, concrete materials, maniuplatives, etc.) to represent phenomena	2.93	2.00	2.79	2.93	2.50	2.00	2.00	2.00
Students made predictions, estimation, and/or hypotheses and devised means for testing them	1.71	2.00	1.57	1.86	1.00	1.50	1.00	1.00
Students were actively engaged in thought provoking activity that often involved critical assessment of procedures.	3.64	3.29	2.86	3.07	4.00	3.00	3.00	3.00
Students were reflective about their thinking	2.50	2.71	1.79	1.93	2.50	2.50	1.00	1.50
Intellectual rigor, constructive criticism, and the challenging of ideas were valued	2.50	2.79	1.64	1.64	2.00	2.50	1.00	1.00
Students were involved in the communication of their ideas to others using a variety of means and media	2.71	2.79	1.86	1.64	2.50	2.50	1.50	2.00
Approximate percent of time was spent in each of the following arrangements:								
Whole Class	47	60	42	33	50	60	43	32
Pairs/Small Groups	28	15	27	7	23	10	0	0
Individuals	25	25	31	60	23	25	29	55

Note: Teachers are identified by the first initial of their last name.

Ms. Baker Observation Overview

				% Time Spent		
Obs	Date	Topic	Inquiry	Whole Class	Small Groups	Ind.
1	1/26/08	Metric System, Multi-Class	No	5	90	5
2	02/06/08	Triangles (on Computers), Multi-Class	Yes	20	80	0
3	02/11/08	Symmetry and CRT Review	Yes	50	0	50
4V	02/20/08	Word Problems, Area, Perimeter (M)	Yes	33	33	33
5	03/05/08	Volume and CRT Review	Yes	33	67	0
6V	03/10/08	Park Assessment, CRT Review (L)	No	50	25	25
7	03/12/08	Equivalent Fractions, CRT Review	For Some	57	21.5	21.5
8V	03/26/08	Logic Problems, Mean, Median	No	60	0	40
9	04/09/08	Graphing Assessment (w/ Computers)	Yes	30	0	70
10V	04/16/08	Ratio Lesson	Yes	50	35	15
11	04/23/08	Scale Drawings	Kind of	67	0	33
12V	04/30/08	Probability (on Computers), Multi-Class (H)	Yes	50	50	0
13	05/08/08	Brain Teasers/Logic Puzzles, Multi-Class	Yes	50	0	50
14	05/12/08	Percents	Yes	100	0	0

Note. V after an observation number indicates the lesson was videotaped.
Note. The (L)ow, (M)id-Range, and (H)igh Scoring Observations for the Observation Protocol are indicated after the topic.

Ms. Fowler Observation Overview

				% Time Spent		
Obs	Date	Topic	Inquiry	Whole Class	Small Groups	Ind.
1	03/18/08	Order of Operations and Parentheses	No	55	18	27
2	03/26/08	Integer Addition and Subtraction (L)	No but…	60	0	40
3	04/09/08	Mixed Number Addition and Subtraction	Tiny Bit	52	26	22
4	04/10/08	Mixed Number Addition and Subtraction (M)	Tiny Bit	58	42	0
5	04/16/08	Multiplication of Mixed Numbers	No	65	0	35
6	04/17/08	Multiplication of Mixed Numbers	No	83	2	15
7	04/23/08	Data Interpretation and Percents	Tiny bit	50	17	33
8	04/24/08	Coordinate Grids	Yes	75	0	25
9	04/30/08	Coordinate Grids, Reflection, Shifts	No	54	0	46
10	05/01/08	Coordinate Grids, Reflection, Shifts	Yes	64	0	36
11	05/02/08	Area of Triangles	Yes	42	42	16
12	05/08/08	Area of parallelograms (H)	Yes	82	0	18
13	05/23/08	Balancing Equations	No	34	44	22
14	05/27/08	Algebraic Expressions	No	62	15	38

Note. The (L)ow, (M)id-Range, and (H)igh Scoring Observations for the Observation Protocol are indicated after the topic.

Ms. Gilbert Observation Overview

				% Time Spent		
Obs	Date	Topic	Inquiry	Whole Class	Small Groups	Ind.
1	01/26/08	Metric System, Multi-Class	No	5	90	5
2	02/20/08	Area and CRT Review	No	67	0	33
3	02/27/08	Area and Volume (M)	Some	95	0	5
4V	03/05/09	Park Project	Maybe	10	0	90
5	03/10/08	Park Project and CRT Review	Kind of	50	0	50
6V	03/12/08	Park Presentations, CRT Review	Maybe	85	0	15
7	03/26/08	Frequency, Mean, Median, Mode	No	25	50	25
8V	04/02/08	Bar Graphs (L)	No	75	25	0
9V	04/09/08	Graphing Assessment	A little	0	0	100
10	04/16/08	Poster Presentations, Brain Teaser	Can Be	67	0	33
11V	04/23/08	Scale Drawings	Yes	15	85	0
12	04/30/08	Probability, Multi-Class (H)	Yes	36	64	0
13	05/08/08	Brain Teasers/Logic Puzzles, Multi-Class	Yes	50	0	50
14V	05/12/08	Fractions to Percents	Yes	18	82	0

Note. V after an observation number indicates the lesson was videotaped.
Note. The (L)ow, (M)id-Range, and (H)igh Scoring Observations for the Observation Protocol are indicated after the topic.

Ms. McClure Observation Overview

				% Time Spent		
Obs	Date	Topic	Inquiry	Whole Class	Groups	Ind
1	02/07/08	Remainders in Division	Yes	55	18	27
2	02/14/08	Coordinate Graphing	No	60	0	40
3	02/25/08	Introduction to Fractions	No	52	26	22
4	02/28/08	Fractions with Pattern Blocks (M)	No	58	42	0
5	03/06/08	CRT Review	No	65	0	35
6	04/01/08	Perimeter or Measurement and Scale Drawing	No	83	2	15
7	04/03/08	Area of your skin	No	50	17	33
8	04/07/08	Area of a parallelogram (H)	Yes	75	0	25
9	04/15/08	Percentages	No	54	0	46
10	04/21/08	Percents and Word Problems with Percents (L)	No Idea	64	0	36
11	04/29/08	Division with Decimals	No	42	42	16
12	05/05/08	Reflections	Almost	82	0	18
13	05/15/08	Weight	No	34	44	22
14	05/20/08	Volume	Yes	62	15	38

Note. The (L)ow, (M)id-Range, and (H)igh Scoring Observations for the Observation Protocol are indicated after the topic.

APPENDIX E

INITIAL INTERVIEW PROTOCOL

OPENING REMARKS TO THE PARTICIPANT:

•I will be taking notes during the interview
•I don't want to miss, misinterpret, or misquote anything that's said
•with permission, the interview will be tape recorded as well
•recorder can be turned off at any time (demonstrate off button)
•everything said is confidential--no personal identification of you, your students, or your school will be made
•transcripts of each interview will be made available if you request them
•additions, deletions, corrections, clarifications are encouraged
•please be as candid as possible–take time to reflect before answering
•if any questions are not clear, stop and ask me to repeat, rephrase, or elaborate

Teaching Background Information

1. I understand that you teach *(grade(s), subject(s), school).* Would you share some specifics about your classes and your students?
   --number and size of classes, subjects, description of students
   --classroom and school setting
   --special/unique duties, situations or problems

2. I'd like to better understand the setting where you teach. What's the community like? How long have you been (teaching at this location/level/subject area)?
   --population, degree of isolation–available resources and facilities

3. Before I visit your classroom, I'd like to know a little more about your curriculum. How do you decide what material you will cover on a given day? What textbook do you use? What other resources to you use in planning your lessons (if any)?

Middle Grades Mathematics Experience

4. I'm curious about your personal experience from the two weeks at Canyon Ferry this past summer. What aspects of it were most meaningful to you?

5. How have your classroom experiences this past fall compared with what you envisioned over the summer after participating in MGM?

6. I'm curious about your action plan. What can you tell me about it?
   -General description
   -Implementation
   -Influence in the classroom

7. I know that *(name)* is your MGM coach. What can you tell me about her visits?
   -Usefulness of visits
   -Value of input

Data Collection Details

8. I'm asking you to keep as weekly journal on inquiry for me. Is there a certain form that you would prefer (written/electronic)? What can I do to help you in keeping the journal?

9. I would like to videotape you classroom somewhat regularly basis. Would you be willing to let me do that? What can I do to make you more comfortable with videotaping?

10. What's the best way to reach you (phone/email, home/school)?
    (Be sure I have contact information)

11. Would you give me idea of your daily schedule so we can decide how I should time my classroom visits?

12. I'd like to set up a tentative plan for visiting your classroom over the next several weeks. Are there any days that definitely won't work? Are any days when you would really like me to visit?

APPENDIX F

INFLUENCES INTERVIEW PROTOCOL

INFLUENCES INTERVIEW PROTOCOL

Note: Part Two of Horizon Research, Inc.'s *Inside the Classroom: Observation and Analytic Protocol* was used as a reference in creating this protocol.

Describe to me what you would consider the ideal situation for facilitating mathematical inquiry in your classroom.

Which aspects are present in your classroom? Which are absent? (Students characteristics?)

Sometimes schools and districts make it easier for teachers to teach using inquiry and sometimes they get in the way. What about your teaching situation influences how you use inquiry?

Do the facilities and available equipment and supplies have any influence on whether or not you use inquiry?

Do you have difficulties getting the materials you need for inquiry lessons?

Does your principal have any influence on your use of inquiry?

Other teachers in the school?

Parents?

Community?

School Board?

District Administration?

Anyone Else?

MGM?

Other Professional Development?

The curriculum? (*If an issue ask for a concrete example of how)*
Is it included in the textbook or program designated for this class?

State/district math assessments? *Which ones do you worry about?*

State and National Standards?

APPENDIX G

"IS IT INQUIRY?" INTERVIEW PROTOCOL

PROTOCOL FOR "IS IT INQUIRY?" INTERVIEW

Emphasize that there are no right or wrong answers and that I'm just interested in their opinions.

Before we start, I'd like you to give me a brief description of what you consider to be the features of inquiry.

I have a few different lessons or activities that I'd like to show you and describe a little bit. Then, I'd like you to tell me whether or not you think each of them is an example of inquiry.

For each activity ask:

Why do/don't you think that is an example of inquiry?

Is there some way that you could tweak this lesson (or the topic of this lesson) so that it would incorporate inquiry?

I'm going to go over the characteristics that were on the "hand" that the teachers at math camp designed last summer. For each of them, I'm curious whether you think that feature must be present for inquiry to occur.

The Hand:

Engaged
Action
Student Centered
Questioning
Building Meaning
Connections
Applications
Discovery
Investigation
Reflection

This isn't on the hand but I was wondering what you thought about "Construction of New Knowledge" as a feature.

Is it possible for something to have several of the features of inquiry but still not be inquiry?

SPINNER GAME

Odd or Even?

Michiko and Patricia are going to play a spinner game. These are the rules:

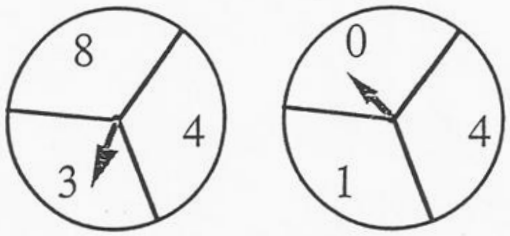
When it is a player's turn, she spins both spinners.

Then she adds the two numbers that the arrows point to.

If the sum is odd (1, 3, 5, 7, 9…), Michiko wins, even if it was not her turn.

If the sum is even (0, 2, 4, 6, 8…), Patricia wins, even if it was not her turn.

Patricia tries a test spin, first. Here is what she spins:



The sum from the first spin is 3, because 3 + 0 = 3. Michiko wins.

Michiko says, "I like this game. I have a better chance to win it than you do."

Patricia says, "No, I have a better chance to win it than you do."

Odd or Even? *Assessment Task*

Use mathematics to decide which girl is right.

Write a note to both girls explaining how you know who has the better chance of winning.

PLACE VALUE ITEM

This year, one million sixty thousand five hundred twenty-seven people came to the state fair. Which number shows the number of people who came to the state fair?

A. 16,527
B. 106,527
C. 1,060,527
D. 1,600,527

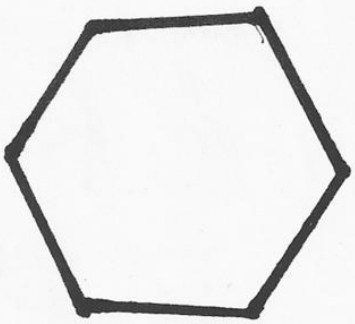
PARTS OF A WHOLE ACTIVITY

Parts of a Whole

Each of the figures below represents 1 whole.

For each one, what fractional part of each figure are the pattern blocks?

A.



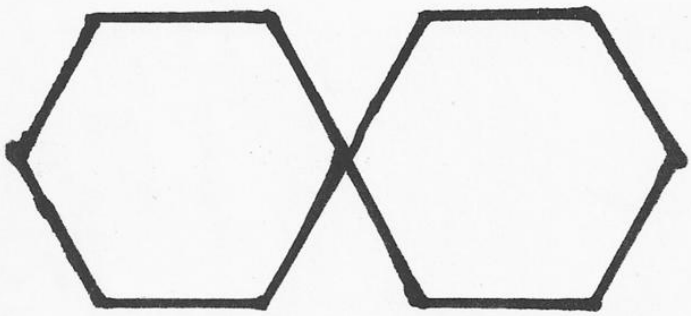
Hexagon _____

Trapezoid _____

Parallelogram _____

Triangle _____

B.



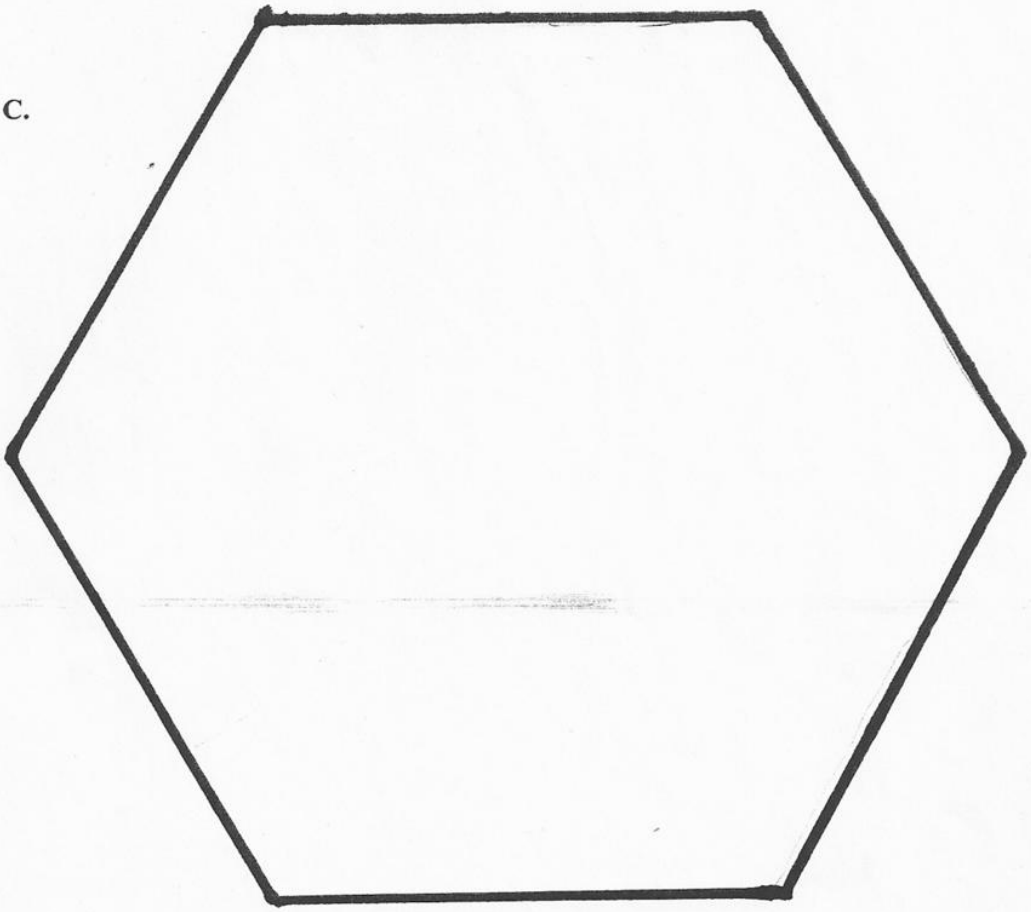
Hexagon _____

Trapezoid _____

Parallelogram _____

Triangle _____

C.

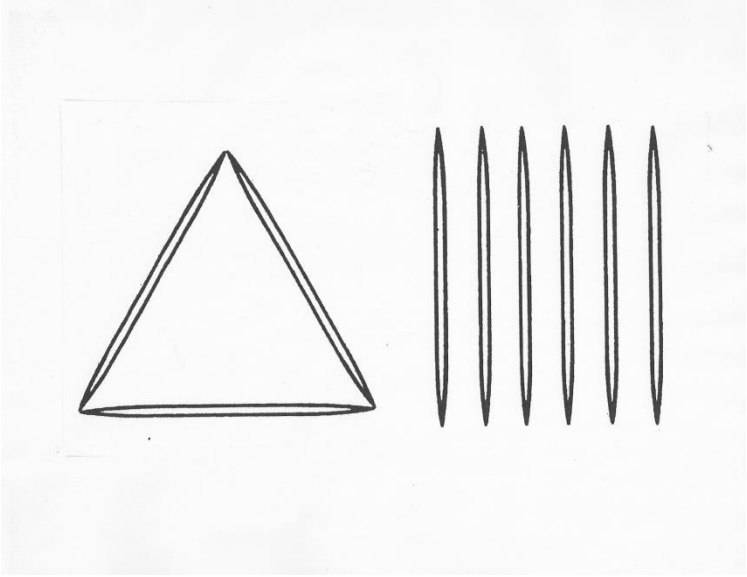


Hexagon _____ Parallelogram _____

Trapezoid _____ Triangle _____

TOOTHPICK PROBLEM

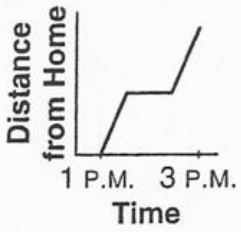
An equilateral triangle made of three toothpicks is shown below. Can you make 4 equilateral triangles using only 6 toothpicks?



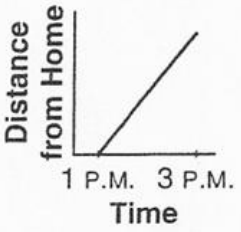
DISTANCE FROM HOME

Luis left his home at 1:00. He walked to a friend's house, played there for an hour, and then walked home. He got home at 3:00. Which graph could show the distance Luis was from his own home between 1:00 and 3:00?

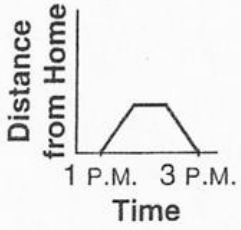
A.



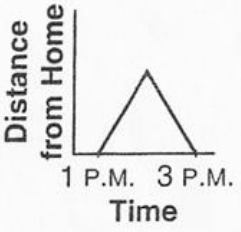
B.



C.



D.



Chapter 12 Final Project

Name _____

To receive an B+	Point values	Grade
Area of 4 places/objects	8	
Perimeter of 4 places/objects	8	
Volume of pool	2	
Needs to be colored	3	
Neatness	3	
Objects to be included		
Outer boundaries	1	
Play area	1	
Picnic area	1	
Pavilion	1	
Pool	1	
bathroom	1	
Total Points	30	

To receive an A on this assignment you may choose two of the concepts in chapter 11 and find a way to incorporate them into your park. The following is a list of the concepts.

Triangles

Quadrilaterals

Congruent figures

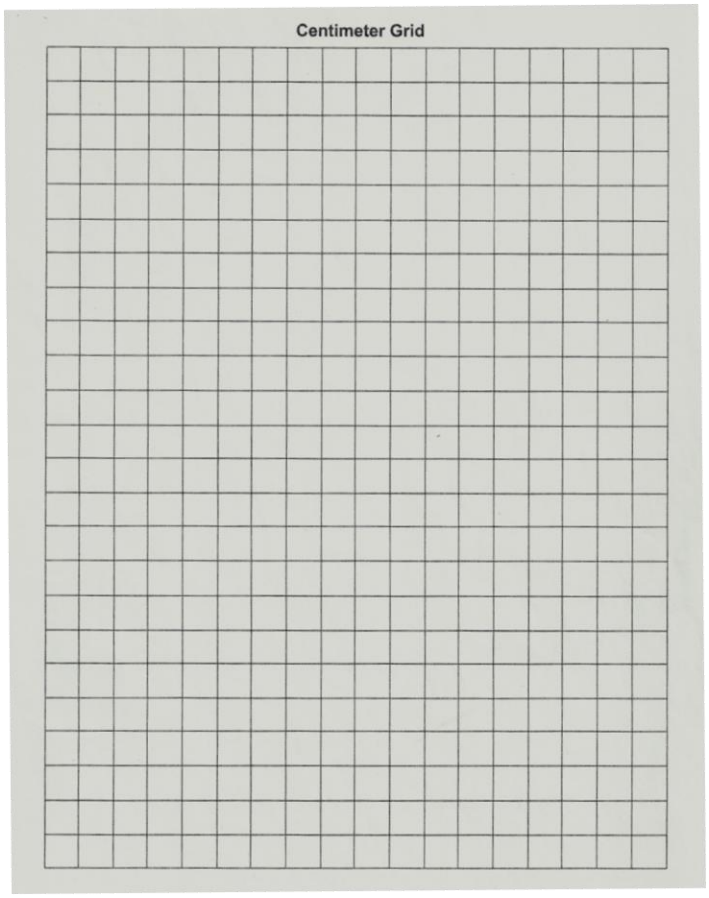
Transformations

Symmetry

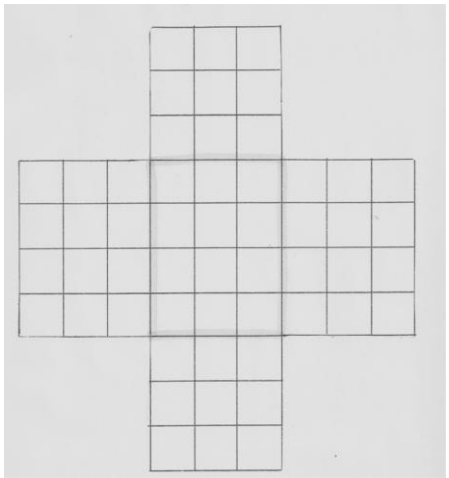
As part of the 30 points, you will need to write a constructed response explaining in pictures, words and/or numbers to show how you found your area and perimeter for your park.

VOLUME FORMULA

Using centimeter grid paper, students cut out nets for open topped rectangular boxes in varying dimensions. Next, students construct boxes from the nets and fill them with centimeter cubes. Then, they write the number of cubes that it takes to fill each box. From there, they look for patterns to predict how many cubes it will take to fill a box.

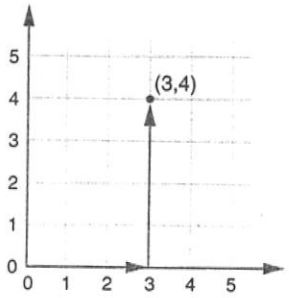






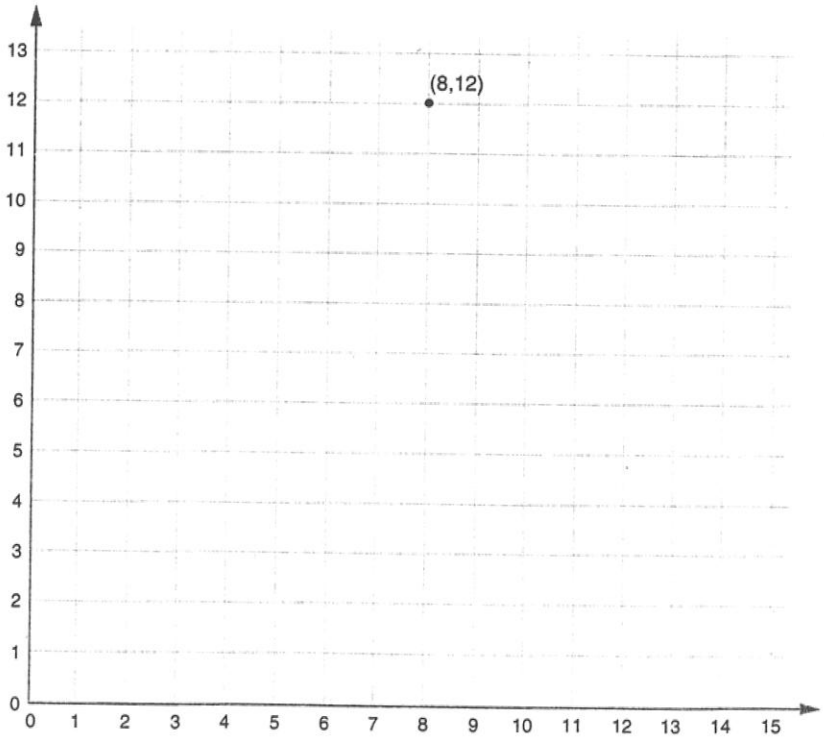
TURTLE PLOTTING

Points on a coordinate grid are named by ordered number pairs. The first number in an ordered number pair locates the point along the horizontal axis. The second number locates the point along the vertical axis. To mark a point on a coordinate grid, first go right or left on the horizontal axis. Then go up or down from there.



Plot an outline of the turtle on the graph below. Start with the nose, at point (8,12).





APPENDIX H

SUMMER INSTITUTE 2008 PERSONAL REFLECTION

Middle Grades Mathematics Projects
July 14-18, 2008
Summer institute Personal Reflection

1. **Overall Reflection:** Reflecting on the past year, describe how (if at all) you have increased your understanding of inquiry-based learning and what it looks like in the mathematics classroom.

2. **Academic Year Reflection**: How (if at all) did the MGM instructional coaching experience support your teaching of mathematics and inquiry during 2007-08? What was the best part of the coaching experience? What suggestions do you have for improving the experience?

3. **Summer 2008 Reflection:** Describe a "personal best" you have achieved during this summer institute in the area of algebra or geometry (e.g., you learned new content or gained a deeper understanding of a concept). Explain what you learned as well as why you consider it a personal accomplishment.

4. **Data for Heather:** Which component of the G2G project helped you the most with implementing inquiry in your classroom? (Please check only one.)

___ 2007 Summer institute (last year)
___ Participating in WebCT activities
___ Creating and using your Action Plan
___ Working with your assigned MGM coach
___ Interacting in other ways with teachers from MGM
___ 2008 Summer institute (this year)