THE STAGES OF TEACHER LEARNING: REFLECTING ON A MATHEMATICS PROFESSIONAL DEVELOPMENT PROJECT

by

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(Under the Direction of Denise S. Mewborn)

ABSTRACT

Teacher professional development is essential to improve our schools' efforts in teaching algebra. This study explored classroom practices and collaboration patterns of middle school teachers 3 years after their participation in a professional learning project focused on student thinking around the topic of algebra. During the 2-year project, teachers participated in content-development courses, engaged in reflection on their teaching, and created communities of learners within and between their schools. Each year of the project, the teachers participated in a 2-week summer institute and monthly study group and lesson study sessions.

This study provided an inside look at teachers' perspectives on the issues surrounding incorporating research findings on best practices in teaching mathematics into their planning and lesson implementation. Because this study followed participants after the end of a professional development project, it provides insight into the elements of the professional development project that were sustained in teacher practice over time. Participants in this study reported confidence in their ability to teach algebra and continued to develop their own mathematical knowledge for teaching by taking graduate level mathematics courses and expanding their teaching certification to additional grade levels. The participants also continued to develop, grow and reflect on their teaching practices after the MSP project; however, some practices such as building community did not appear to have as strong a continuation for the participants.

INDEX WORDS: Mathematics Education, Professional Development, Mathematical Knowledge for Teaching, Collaboration, Algebra

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DEDICATION

I would like to dedicate this work to my daughters Brynn and Emory for their constant love, support, and inspiration.

ACKNOWLEDGEMENTS

I would like to thank my committee members for their patience and prodding during my time at University of Georgia. I have learned so much from each of you and am thankful for the opportunity to continue growing and learning. I am especially thankful to my committee chair, Denise Mewborn for knowing just when I needed extra support and encouragement along this journey.

As I approached this study, I spent a great deal of time reflecting on my professional experiences up to this point. I realized a critical point in my growth as a mathematics teacher came one summer when I took a course called, "Math and the Mind's Eye." I would like to express sincere gratitude to the author of that course, Linda Foreman. Over the years you have challenged me to become a better mathematics teacher, professional developer, and person.

I appreciate and respect the mathematics teachers in my district and I especially thank the participants in this study. Your willingness to share your thoughts about your classroom practice with me was an awesome experience. I have learned so much from each of you!

I would like to thank my parents for instilling in me the belief that I can do anything I set my mind to do – just like the Little Engine. And finally, to my husband Mike, thank you for encouraging me and pushing me to finish. I can't wait to experience family time with you, Brynn and Emory while this study sits on the bookshelf in the den!

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CHAPTER 1

INTRODUCTION

Background

One of my first assignments as a district mathematics coordinator was to lead a group of high school and middle school mathematics teachers through a discussion on allowing algebra to be taught in middle school. I had been both a high school and middle school mathematics teacher, and my hope was that we could begin allowing students the opportunity to study algebra earlier than high school. As the meeting began, I quickly realized the political, philosophical, and equity issues that existed within the group. The high school teachers arrogantly addressed the middle school teachers and dismissed the idea of algebra in the middle school using their own anecdotal experiences with unprepared students as the rationale. The middle school teachers had no voice during the meeting because I had not created a safe environment for the discussion. At the end of the meeting, we took a vote and decided that students could not take algebra any earlier than high school. I remember leaving that meeting filled with questions. Why do I think students should be allowed to study algebra earlier than high school? What experiences helped me develop my teaching philosophy that included having mathematical trust in students? Should I trust the content knowledge of the middle school teachers if they do not trust themselves?

I had been involved in a number of professional development experiences and had worked side by side with many of the members of this group, so I kept wondering what made me change my practice and ideas about student learning. The draft version of *Curriculum and Evaluation Standards for School Mathematics* (National Council of Teachers of Mathematics [NCTM], 1988) had been part of my undergraduate methods courses, so I came into the profession with a mission to create a classroom like the ones described by NCTM. I had spent my first few years of teaching trying out ideas, reading journals like *Mathematics Teacher,* and attending professional development sessions. In reflecting, I think one critical point in my professional development came while I participated in a workshop focused on solving algebra problems using multiple representations. Through the use of classroom videos, this workshop encouraged my curiosity about how my students might think about the problems we were working.

Much of my work as mathematics coordinator has focused on creating opportunity for teachers in my district to have that critical point of reflection that causes changes in their practice. I knew we needed outside help to keep us moving forward, so we applied for a state Mathematics and Science Partnership (MSP) grant with university partners and began work. The goal of the project was to make a significant impact on the teaching of mathematics and science by increasing teacher content knowledge and collaboration with colleagues and higher education partners. During the 2-year project teachers participated in content-development courses, engaged in reflection on their teaching, and created communities of learners within and between their schools. Each year of the project, the teachers participated in a 2-week summer institute and monthly study group and lesson study sessions. Now that the grant has ended, this study explored the participants' thinking 3 years later.

Problem

In recent years, concerns have been growing about the teaching of algebra. Middle and high school algebra courses have been identified as gateways for a variety of future career opportunities. That is, children who do not take algebra are shut out of mathematics-related careers in science, including medicine, engineering, business, etc. (Silva, Moses, Rivers, & Johnson, 1990). Nationally, high school students who take one year or more of algebra are two to three-and-a-half times more likely to attend college than students who do not take algebra (Miner, 1995). To compound this problem, many students learn algebra as only a series of manipulations applied to meaningless strings of symbols. Students are not encouraged to think algebraically and to make connections between algebra and their world. Doubts have been raised about whether algebra as currently taught is adequate to the needs of today's students in relation to the rapid advances in technology (Schifter, 1997).

How well teachers know and understand algebra is central in supporting student understanding (Schifter, 1997). It is not surprising that many teachers who have been through the U.S. educational system lack sound mathematical ability and skill because studies over the past 15 years consistently reveal that many U.S. teachers have not developed a profound understanding of fundamental mathematics (Ma, 1999). Because of this surface level understanding of mathematics, many teachers have not focused on individual student thinking in the mathematics classroom but have instead spent time engaging in whole-group learning activities that do little to address the needs of individual learners. In addition, the idea that students come to algebra class with distinctly different ways of operating quantitatively and numerically is vital to helping teachers support students' development of algebraic knowing (Steffe, 2002).

Borko (2004) suggested this focus on student thinking must be one of the key elements of professional development for today's algebra teachers. Professional development must use student thinking as a tool that engages teachers and helps make explicit their own thinking about their students' thinking.

Another key principle of mathematics professional development is creating communities where the teachers are engaged in inquiry. Sarason (1996) argued that a key to teachers' ongoing growth lies in creating school cultures where serious discussions of educational issues occur regularly and where teachers' professional communities become productive places for teacher learning. Such schools, he argued, can replace teacher isolation with cultures of collaboration (Sarason, 1996). Learning in ways that continue to be generative over time is best done in a community of fellow practitioners and learners (Kilpatrick, Swafford, & Findell, 2001). Professional development can create contexts for teacher collaboration, provide a focus for the collaboration, and provide a common frame for interacting with other teachers around common problems such as focusing on student understanding of algebra.

Research is needed to help teacher educators better understand how professional development influences the work of mathematics teachers over time. Exploring this idea requires coming to understand what it means for a teacher to engage in ongoing learning and then how professional development influences or contributes to changes in his or her practice. Through this study I aimed to provide the research community with an inside look at teachers' perspectives on the issues surrounding incorporating research findings on best practices in teaching mathematics into their planning and lesson implementation. Because this study followed participants after the end of a professional development project, it provides insight into the elements of the professional development project that were actually sustained in teacher practice over time. The research questions that guided the study are as follows:

1. How does participation in a mathematics professional development program support participating teachers' self-assessment of their mathematical knowledge for teaching?
2. How do teachers think their participation in a mathematics professional development program focusing on student thinking has influenced their mathematics teaching?
3. What perceived changes occur in participating teachers' patterns of collaboration with colleagues during and after the professional development program?

CHAPTER 2

LITERATURE AND THEORETICAL FRAMEWORK

Literature Review

In this section, I review literature on mathematical knowledge for teaching, professional development, and collaboration. An overarching goal of the Mathematics and Science Partnership (MSP) project mentioned in chapter 1 was to increase teachers' content knowledge in mathematics, so this review of literature encompasses research in mathematical knowledge for teaching. In the section on professional development, I specifically look at professional development focused on classroom practice, the use of video as a tool for reflection, and implementation of the lesson study process. Each of these areas is included because the MSP project included these professional development strategies. Because a goal of the MSP project was to create a community of learners, research on collaboration is also included.

Mathematical Knowledge for Teaching

The need to further understand the profession of mathematics teaching has led to the use of a phrase to describe the complicated work of teaching mathematics, *mathematical knowledge for teaching* (MKT). MKT is used to describe the mathematical knowledge, skill, and insight needed for the work of teaching (Ball, Thames, & Phelps, 2008). This idea is also referenced in *Adding It Up* (Kilpatrick et al., 2001):

> Conventional wisdom holds that a teacher's knowledge of mathematics is linked to how the teacher teaches. Teachers are unlikely to be able to provide an adequate explanation of concepts they do not understand, and they can hardly

> engage students in productive conversations about multiple ways to solve a problem if they themselves can only solve it in a single way. (p. x)

Given this statement, understanding the work of teaching mathematics is complex and layered. In addition to understanding mathematics content for themselves, teachers need knowledge of how students learn mathematics; however, debate continues with regard to how much mathematics and what type of mathematics pedagogy courses are needed by teachers.

Current thinking around MKT has been built upon the work on pedagogical content knowledge by Shulman (1986). Pedagogical content knowledge can be described as a special kind of knowledge that links content to pedagogy. Shulman made a call for researchers to build a framework that reflected both content knowledge and what he called *pedagogical content knowledge.* He suggested that teacher content examinations for licensure contain more than just subject matter. He envisioned an assessment that contained both content and pedagogy because, he argued, there is a difference between the work of a mathematician and the work of a mathematics teacher.

Ball, Thames, and Phelps (2008) revisited Shulman's work with a focus on the actual classroom practice of mathematics teachers. Initially Ball's team used two categories to identify the work of teaching: mathematics knowledge and knowledge of students and mathematics. Extension of this work has resulted in a practice-based theory of mathematical knowledge for teaching. The researchers have explored mathematics classrooms looking for answers to questions such as, "What are the skills and attributes that are part of an effective mathematics teachers practice?"

Currently, Ball and colleagues have taken the approach that MKT has six major components: common content knowledge, specialized content knowledge, knowledge of content and student, knowledge of content and teaching, horizon content knowledge and knowledge of content and curriculum. *Common content knowledge* (CCK) is described as the mathematical knowledge and skills used in settings other than teaching. Because everyone uses mathematics, common content knowledge is a general understanding of mathematics. In addition to CCK, teachers need to be able to respond to students when they ask "why" questions or give a mathematical explanation. This type of knowledge is unique to teaching and has been termed *specialized content knowledge* (SCK). Understanding the relationship between students and mathematics is the third major component of MKT. *Knowledge of content and students* (KCS) helps teachers think through a lesson to make predictions about how students may respond when the lesson is implemented and what students are likely to find confusing. Planning for a lesson also requires a fourth component, *knowledge of content and teaching* (KCT). KCT is the part of planning the lesson that involves selection of specific examples or determining the order student examples should be shared during a lesson.

Horizon content knowledge is described as having an awareness of the mathematics topics across grade levels and the relationship between the topics. *Knowledge of content and curriculum* is a category described in the work by Shulman (1986). Shulman used the terms *lateral* and *vertical* to provide more explanation of curricular knowledge. Lateral curricular knowledge allows teachers to make connections between the content they are teaching and other subjects while vertical curricular knowledge requires knowing the content before and after the course you are teaching. Ball et al. (2008) suggest that as additional study in this area is conducted, the categories that are currently proposed may change.

Measuring MKT has been complicated. Historically, teachers have taken examinations based on subject matter to qualify for teaching credentials (Hill, Sleep, Lewis, & Ball, 2007). Recently, some standardized protocols for observing mathematics classrooms in relation to MKT have emerged. In addition, researchers have used various paper-and-pencil instruments to measure MKT. Instruments such as Learning Mathematics for Teaching (LMT) (Hill, Schilling, & Ball, 2004) contain items that represent mathematics problems that are encountered in classroom practice. The concept of MKT is still developing, so deciding what to assess has been one of the most challenging aspects for each of the assessment projects. Because the theoretical framework associated with MKT is continuing to expand, the current MKT paper-and-pencil assessments have a certain subset of knowledge and skills that are assessed and reported. Hill et al. (2007) state, "Valid teacher assessments should not be remote from what teachers are asked to do in classrooms, with real students, materials, and content" (p. 150).

Professional Development

Factors influencing professional development. Professional development programs are systematic efforts to bring about change in the classroom practices of teachers, in their attitudes and beliefs, and in the learning outcomes of students (Guskey, 2002). The improvement of the professional practice of teachers is seen as integral to the effort to improve K-12 education. In *Adding It Up*, the National Research Council (NRC; Kilpatrick, Swafford, & Findell, 2001) report on mathematics education in the United States, continuing professional development is cited as critical for developing proficiency in teaching mathematics. Prior work on professional development has suggested that effective professional development needs to include long-term engagement with issues closely related to the work of teaching. Sowder (2007) suggested the following goals for professional development: (a) a shared vision for mathematics teaching and learning, (b) a sound understanding of mathematics for the level taught, (c) an understanding of how students learn mathematics, (d) deep pedagogical content knowledge, (e) an understanding of the role of equity in school mathematics, and (f) a sense of self as a mathematics teacher.

According to Clewell et al. (2005), professional development that focuses on increasing teacher knowledge of the subject matter, on a specific curriculum, or on the student learning process is more likely to be effective in terms of increasing student achievement than professional development that focuses only on teacher behaviors. The underlying assumption of professional development programs for teachers of mathematics in Grades K–12 is that student achievement increases as teachers deepen and broaden their knowledge of mathematics content and pedagogy. Cooney (1994) states, “Being an adaptive agent in the classroom requires a great deal of knowledge about mathematics, pedagogy, and the psychology of learning” (p. 9). In order for teachers to be truly effective educators in mathematics, they must fully understand the content, have instructional tools to teach and assess student learning, and appreciate how children develop an understanding of the material presented to them (Garet, Porter, Desimone, Birman, & Yoon, 2001). Garet et al. (2001) found that by increasing teacher content knowledge in mathematics, positive changes in instruction occurred. Teachers were better equipped to understand student misconceptions about the subject matter and were able to facilitate student learning of mathematics using a more meaningful approach. If teachers have only a shallow understanding of mathematics, they may not be able to support and extend student thinking and are likely to resist a student-centered classroom environment.

The Garet et al. (2001) study was one of the first large-scale empirical comparisons of effects of different characteristics of professional development on teachers' learning. The study included a national probability sample of 1,027 mathematics and science teachers and asked the question, "What makes professional development effective?" The study examined self-reported change in classroom teaching practice and teachers' knowledge and skills. One limitation of this study is that the perception of the participants could be in contrast to their actual classroom practice. During the process of analyzing the Third International Mathematics and Science Study (TIMSS) data, Stigler and Hiebert (1999) found teacher interview responses in conflict with their videotaped classroom episodes, leading researchers to conclude that teachers knew the ideas that were valued but did not have the same understanding of implementation of the ideas.

Video use in professional development. Professional development programs that incorporate video as an artifact of practice have reported that teachers can have meaningful discussions with their colleagues around video from their own classrooms. Sherin and Han (2004) documented a year-long professional development program for four mathematics teachers at the same middle school. The teachers met regularly throughout the school year to view video excerpts from their own classrooms. Video was used to help teachers learn to critically notice and interpret classroom interactions. Through qualitative research methods, Sherin and Han reported that conversations between participants evolved in important ways over time, and studying this evolutionary process enabled them to describe what and how the teachers learned from their participation. One limitation of this study was the small sample size that was used. Generalizations from this study may therefore be limited.

Lesson study. Another professional development design that may complement reviewing one's own videotaped lessons is lesson study. Based on their research on Japanese teaching methods, Stigler and Hiebert (1999) suggest lesson study as an opportunity for collaborative professional development in the United States. The school-based professional development process that Japanese teachers employ provides teachers with mentoring and training while working on the work of teaching. Teachers begin the process by identifying a lesson study goal and the lesson content. The group of teachers then spends time collaborating on a lesson that over a period of time will be taught, revised, and taught again. Throughout the process, the teachers work together to think through how students might respond to particular parts of the lesson and then after the lesson is taught to analyze how students actually responded. The lesson study process provides teachers with an opportunity to slow down and think through the work of teaching.

Fernandez, Cannon, and Chokshi (2003) explored the process of implementing lesson study with a collaborative group of 28 American and Japanese teachers. The Japanese teachers served in the role of coach during the process. Although the process was described to the teachers as a form of systemic research, in-depth analysis of the planning session transcripts found that the American teachers had difficulty determining and keeping focus on their research lens while planning the lesson. This lack of focus was also evident as the teachers discussed how students would solve the problems of area of a triangle that they had developed. The discussion stayed on the surface level and did not begin to uncover what a student responses might mean about how the student understood the idea of area or how to facilitate the student's understanding. An important aspect that was shared by the Japanese teachers was "the importance of teachers adopting the student lens by attempting to understand students' thinking, anticipate their behaviors, and determine how to use this knowledge to build students' understanding" (p. 179).

Teacher learning over time. Effective instruction in mathematics "requires an appreciation of mathematical reasoning, understanding of the meaning of mathematical ideas and procedures, and knowing how ideas and procedures connect" (Hill & Ball, 2004, p. 331). In an effective mathematics classroom, activity centers on mathematical understanding, invention, and sense-making by all students (Kilpatrick et al., 2001). To guide student thinking, teachers must also understand how children's ideas about a mathematical topic develop and the connections between their ideas and important ideas in the discipline (Schifter & Fosnot, 1993). Research on the Cognitively Guided Instruction (CGI; Carpenter, Fennema, Peterson, Chiang, & Loef, 1989) project shows that professional development can help teachers construct these understandings. The CGI project focused on children's thinking in addition to building teacher content knowledge. The teachers who participated in the 4-week summer CGI workshop knew more than control group teachers about the strategies that children use to solve problems, the kinds of problems they find difficult, and different ways to pose problems to students. The teachers also reported an increased awareness of the role that children's thinking plays in the learning process and the importance of listening carefully to students in order to build on their understandings and misconceptions. During the analysis stage of the project, benchmarks were created to describe the participants' level of engagement with children's mathematical thinking:

Level 1: The teacher does not believe that the students in his or her classroom can solve problems unless they have been taught how.

Level 2: A shift occurs as the teachers begin to view children as bringing mathematical knowledge to learning situations.

Level 3: The teacher believes it is beneficial for children to solve problems in their own ways because their own ways make more sense to them, and teachers want the children to understand what they are doing.

Level 4A: The teacher believes that children's mathematical thinking should determine the evolution of the curriculum and the ways in which the teachers individually interact with the students.

Level 4B: The teacher knows how what an individual child knows fits in with how children's mathematical understanding develops.

In a follow up study with 22 of the original CGI project participants, Franke, Carpenter, Levi, and Fennema (2001) found that teachers who had a high level of implementation during the professional development project continued to have a high level of classroom implementation of the strategies learned 4 years after the project's end. In addition, these teachers were described as experiencing generative change because of their continued learning from the experiences within their classroom and with their colleagues. In the case studies, teachers at Levels 4A and 4B continued to provide opportunities for students to use a variety of strategies and to talk about their thinking. These findings support the claim that professional development focusing on student thinking can provide a means for engaging teachers in generative growth.

Collaboration

Studies of school reform demonstrate that powerful change can occur when the focus of the reform extends beyond the individual teacher (Hargreaves, 1996; Little, 1993). Collaboration among teachers seems to produce a greater willingness to take risks, learn from mistakes, and share successful strategies (Ashton & Webb, 1986). Just as classrooms promote student learning by becoming communities of learners where students collaborate to investigate topics in depth, engage in collective reflection, and challenge each others' thinking (Cobb et al., 1991), schools foster teacher learning when they become communities where teachers engage in challenging one another's thinking. The goal then is to create opportunities for teacher learning through professional communities whose activities are embedded in teachers' everyday work (McLaughlin & Talbert, 1993). As an example, the QUASAR project (Stein, Smith, & Silver, 1999) sought to improve mathematics instruction for students attending middle schools in economically disadvantaged neighborhoods by funding and studying six site-based professional development programs. In the QUASAR project, professional learning communities were central to fostering teacher change and student learning. For example, at schools where strong communities evolved, teachers increased their use of cognitively challenging tasks and students' mathematical explanations. Students in these QUASAR schools grew in their ability to solve problems and communicate mathematically. Grossman and colleagues' (2001) insights about teacher community suggest a conceptual explanation for these findings. They argued that we cannot expect teachers to create a community of learners among students if they do not have a parallel community to nourish their own growth. The logic of this claim makes sense, but as a research community we have yet to build an empirical base to support the claim or to shed light on the mechanisms by which this relationship works (Borko, 2004).

In the Georgia Partnership for Reform in Science and Mathematics (PRISM) project, a National Science Foundation (NSF)-funded Mathematics and Science Partnership (MSP), K–12 mathematics and science educators worked together with higher education faculty to establish learning communities (LCs). The team developed a rubric to describe the levels of implementation of their professional learning communities (see Appendix A). The learning community rubric has strands for shared vision, P-16 faculty collaboration, shared leadership, collaborative inquiry and making the results public. For each indicator (strand), there is a brief written description of the different levels of performance based on performance criteria.

PRISM LCs were expected to have P–16 educators on the team and to meet regularly with the purpose of improving student learning. The LCs throughout the state designed their team activities around needs within their group. For example, one LC focused on Advanced Placement Calculus. The team shared resources, shared teaching strategies for specific standards, and provided support to colleagues throughout the year. PRISM (2007) reported that statewide, teachers who participated in PRISM LCs reported greater emphasis on standards-based teaching and learning practices than those who did not. They also reported that teachers who participated in PRISM LCs that had a higher education faculty member involved reported greater emphasis on inquiry-based teaching and learning than participants in a PRISM LC that did not have higher education faculty involvement.

Theoretical Framework

The present study examined ways in which teachers perceive changes in their practice after completing a professional development program focused on student thinking. Transformative learning theory describes the conditions and processes necessary for teachers to make the most significant kind of knowledge transformation: paradigm shift, also known as perspective transformation. Mezirow (2000) developed the theory of transformative learning by integrating a number of theories, models, and ideas from a wide variety of sources. The theory continues to evolve through the inclusion of new perspectives on adult learning and development.

We expect what has happened in the past to happen again. If we have failed to understand mathematics, we expect to continue to fail in this subject. If we have had students not understand algebra, we expect students to continue to be confused by algebra. The habits of mind that are established may have to do with our sense of self, interpretation of social systems and issues, morals and religious beliefs, and job-related knowledge. It is easier and safer to maintain habits of mind than to change. It may take a significant or dramatic event to lead us to question assumptions and beliefs. Other times, though, we engage in an incremental process in which we gradually change bits of how we see things, not even realizing a transformation has taken place until afterward. Critical reflection occurs when we work through beliefs and assumptions, assessing their validity in the light of new experiences or knowledge, considering their sources, and examining underlying premises. In applying transformative learning theory to teaching, Foreman (2003) developed a model of teaching in transformation. The stages of the model are represented in Figure 1.

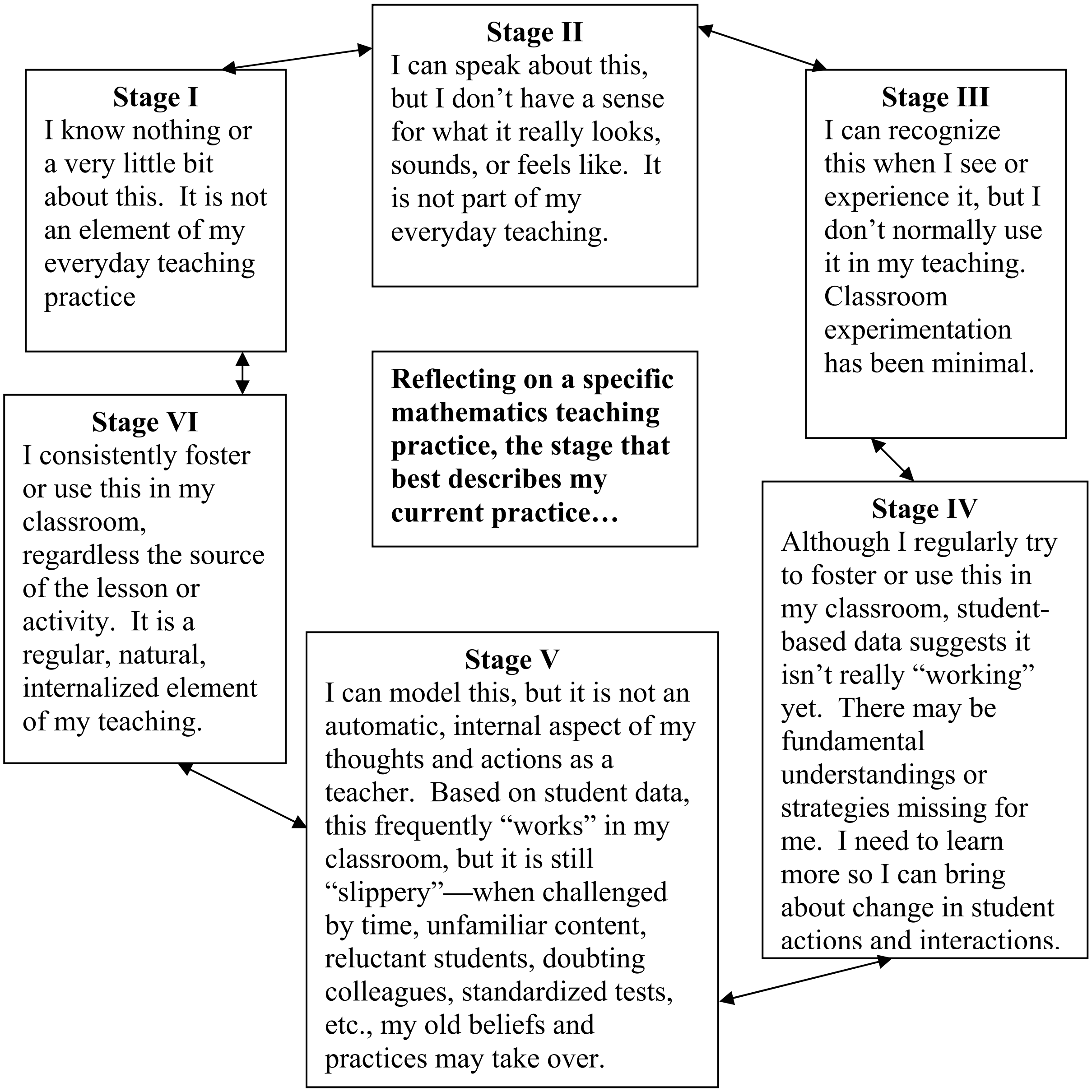

Figure 1. Stages of teaching in transformation.

From (Foreman, 2003, p. 42). Used by permission.

In this model, a teacher can be moving forward through the stages with regard to a certain practice when something causes a setback or slide. In an interview with Linda

Foreman (personal communication, December 8, 2009), she noted that the arrows in this model indicate that movement between the stages is fluid, going both forward and backward. This model was used in the professional development during the MSP project to introduce the participants to reflection on their practice. Teacher reflection is vital throughout the process of learning and implementing new practices in teaching. I used this model to frame the questions that I asked the participants and in the analysis of the data that were collected.

CHAPTER 3

METHODOLOGY

I used qualitative methods to address the research questions. Changes in participants' classroom practices and collaboration patterns were identified based on the qualitative methods of grounded theory. Grounded theory is a process by which a researcher generates theory that is based or grounded in the data (Crotty, 2003). The data for this proposed study included some archived data. Additional data were collected through focus groups and interviews.

Table 1 provides additional details. It shows the alignment between research questions and data sources.

Table 1

Research Questions and Data Sources

Research question	Data source
How does participation in a mathematics professional development program support participating teachers' self-assessment of their mathematical knowledge for teaching?	Archived Learning Mathematics for Teaching (LMT) pretest/posttest score comparison for the pd period Archived District Instructional Practices Survey Analysis of Interview transcripts Analysis of Teacher Certification and advanced degrees Analysis of Teacher Reflection Tools Stages Survey
How do participating teachers think participation in a mathematics professional development program focusing on student thinking has influenced their mathematics teaching?	Archived MSP Evaluation Survey data Analysis of Interview and Focus Group transcripts Analysis of participant classroom video reflection from interview

What perceived changes occur in participating teachers' patterns of collaboration with colleagues during and after the professional development program?	Analysis of Teacher Reflection Tools Stages Survey Archived MSP Evaluation Survey data Archived District Instructional Practices Survey Analysis of Interviews and Focus Group transcripts

Context

This study was a follow-up to a Mathematics and Science Partnership (MSP) project. The MSP project partnered the school district with two higher education institutions with a goal of making a significant impact on the teaching of mathematics and science. During the 2-year project teachers participated in content-development courses, engaged in reflection on their teaching, and created communities of learners within and between their schools. Each year of the project, the teachers participated in a 2-week summer institute and monthly study group and lesson study sessions. Figure 2 describes the grant activities over the 2-year period.

Year 1	Year 2
Summer Institute • Cohort ~48 mathematics and science teachers • Two-week institute focusing on Best Practices in Teaching Mathematics and Science with mathematics and science content courses • Institute will be led by consultant, Higher Ed faculty & district team	**Summer Institute** • Cohort ~48 mathematics and science teachers • Two week institute focusing on Designing Groupwork in Mathematics and Science with mathematics and science content courses • Institute will be led by consultant, Higher Ed faculty & district team
Leadership Team Training Academy • Mathematics and Science Teachers in Residence • Monthly meeting on building a collegial community through vertical team activities with mathematics and science content	**Leadership Team Training Academy** • Mathematics and Science Teachers in Residence • Monthly meeting on building a collegial community through vertical team activities with mathematics and science content

• Training will be performed by district team	• Training will be performed by district team
Implementing the Georgia Performance Standards through the Lesson Study Process • Cohort ~48 mathematics and science teachers • Training will be performed by consultants	**Implementing the Georgia Performance Standards through the Lesson Study Process** • Cohort ~48 mathematics and science teachers • Training will be performed by district team
Mathematics and Science Content Courses • Middle school teachers will begin graduate coursework in mathematics and science • Courses taught by higher ed faculty	**Mathematics and Science Content Courses** • Middle school teachers will continue graduate coursework in mathematics and science • Courses taught by higher ed faculty

Figure 2. MSP grant activities. [district website]

In the first summer institute, all grant teachers participated in the Best Practices for Teaching Mathematics course and a content course developed and taught by two mathematics faculty members at one of the higher education partners. The goals of the Best Practices for Teaching Mathematics course were to develop skills that teachers need to promote discourse, support problem solving, implement inquiry-based approaches, challenge all of their students, and become reflective practitioners. The course engaged teachers in mathematics content as a way of thinking about how to teach in their own classrooms. The workshops were begun in the summer, with 2 days of follow-up activities during the school year.

The second summer institute included the Designing Groupwork course and another content course developed and taught by two mathematics faculty members of the higher education partner. The Designing Groupwork course supported teachers in thinking about when and how to implement collaborative learning in their classrooms. Topics included strategies for managing collaborative learning environments, determining when to use collaborative strategies, developing groupworthy tasks, promoting discourse in the mathematics classroom, and working with status issues in the classroom.

During each year of the grant, the lesson study cycle was conducted with a focus on algebra. Teams of grant teachers met monthly to plan lessons together. Structured protocols were used throughout the process to guide the development of the lessons and the group discussions regarding the teaching and revising of the lessons. Table 2 shows one example of a protocol used during the teaching and revising stage of the lesson study cycle.

Table 2.

Data Driven Dialogue Protocol (Love, 2002).

Phase	Actions
Phase I	Prediction Surfacing perspectives, beliefs, assumptions, predictions, possibilities, questions, and expectations
Phase II	Observation Analyzing the data for patterns, trends, surprises, and new questions
Phase III	Inference Generating hypothesis, inferring, explaining and drawing conclusions

Before a lesson was taught, each teacher would identify one to two questions to collect data on during the observation. The DDD protocol required the teachers to predict what they might see during the observation. During the observation phase, the teachers would observe the student actions and keep a record of all data collected. At the end of the observation, the teachers would meet in a group to record all of the facts they had collected. The DDD protocol helped the teachers slow down the process of reflecting on the lesson so that only facts were listed, no inferences at this stage. The last phase of the DDD protocol allowed the participants to share inferences related to the facts and also to plan the next steps for the lesson. This process was facilitated by a consultant from outside the district during the first year of the grant. The entire process was conducted four times during each year of the grant.

In order to provide teachers with opportunities to reflect on their teaching practice, videotaping techniques were utilized during the project with the support of one of the higher education partners. By using the video-based data collection system, the teachers were able to reflect and label specific actions as evidence of their implementation of the best practices learned during the professional learning sessions.

Because this study followed participants after the end of the MSP project, it provides insight into the elements of the professional development project that were sustained in teacher practice over time.

Setting

This study was conducted in a public school district in Georgia. The school district serves over 33,000 students in Grades K–12. Of that population, some 8,000 students are in Grades 6–8. For purposes of Adequate Yearly Progress (AYP) and other reports, Georgia defines economically disadvantaged students as those pupils who are eligible for free or reduced price lunch. Overall, some 70% of the students in the district were eligible for free or reduced price lunch. At the time of the MSP project, of the 12 schools in the district serving middle grades students, most did not make AYP for the 2004–2005 school year. More recent data shows that only one middle school in the district did not make AYP in 2009.

The district's Certified Personnel Information Report for 2004 indicated that about three-fourths of the district's certified middle school teachers were female and more than half were African American. The district had approximately 80 middle grades mathematics teachers. Before the MSP project, about a fourth of those teachers were categorized as not having a major in mathematics. At the conclusion of the MSP project in 2006, the Certified Personnel Information Report indicated that only one-eighth of the middle grades mathematics teachers did not have a major in mathematics.

Participants

The sample for the present study consisted of middle school mathematics teachers in a Georgia public school district that participated in the district's Mathematics and Science Partnership (MSP) professional development activities from 2005 through 2007. Of the original 24 participants, 8 were still working in the district at the time of this follow-up study and also had archived videos of their teaching from the project.

All of the eligible participants were asked to participate in this study. Five agreed to participate, and all eight of the participants' archived data were used. At the time of the MSP project, all eight participants were teaching middle grades and had middle grades mathematics certification. One of the participants also had high school mathematics certification. During the time between the MSP project and this study, three of the participants became mathematics coaches for the district, and one participant began to teach high school mathematics. One participant added an early childhood mathematics endorsement to her certification, and two participants were certified in high school mathematics. Table 3 shows the highest degree earned by the group before the MSP project and at the time of this study.

Table 3.

Number of Participants by Highest Degree Each Year

Highest degree earned	2004	2009
Bachelor's	7	1
Master's	1	2
Education specialist	0	5

In this section I provide a brief description of each of the participants in the study. All participants' names are pseudonyms.

Alicia had been working in the district for 13 years. She moved in her first 3 years from teaching high school social studies and mathematics to just teaching mathematics. She moved to middle school at the beginning of the MSP project, choosing to be a part of a district sponsored charter school. In the charter setting, she attended numerous professional development sessions mostly on school culture. Her participation in the MSP grant activities was part of the charter school requirements. The summer after the MSP grant ended, Alicia was selected to be an elementary mathematics coach. She added early childhood certification at that time and began working on her master's degree in teaching and learning. She earned her specialist degree in educational leadership and teacher support specialist certification in December 2009. At the time of this study, Alicia was a high school mathematics coach.

Daniel had been teaching for 26 years at the time of the interview. He began his teaching career with elementary certification and made the transition to middle school in 1985. He had actively participated in a number of professional learning sessions throughout his career including sessions focusing on manipulative use in the classroom and project-based learning. He completed his master's degree requirements in 2003. The focus of his thesis was on project-based learning in the mathematics class. Daniel described his participation in the MSP project as mandatory in the beginning, but in the second year of the project he voluntarily attended additional sessions that were not required.

Jessica had been teaching for 13 years. She had begun teaching by teaching middle school mathematics. She taught sixth grade the first 5 years and was teaching eighth grade at the time of the MSP project. She had participated in curriculum writing teams at the district level with colleagues from around the school system. She was considered a leader in her building and had been chosen by her principal to participate in the MSP project. At the time of this study, Jessica had changed schools and was teaching seventh grade. Her new school was in a sixth- through twelfth-grade building, so she had also decided to add secondary certification prior to making the change.

Susan was in her first year of teaching when the MSP project began. She and Jessica taught eighth grade at the same school. Susan attended every MSP session that was offered. She was eager to try lessons and openly shared her experiences with others in the project. When the assistant principal at her school became an elementary principal, Susan was asked to move to teach fifth grade. She made the transition and also added the early childhood mathematics endorsement to her certification. At the time of this study, Susan had returned to teaching eighth-grade mathematics.

Valerie had been teaching middle school mathematics for 16 years, mostly in eighth grade. She became a teacher leader in her school in 2005 and added the teacher support specialist endorsement to her certification. The same year, she completed her master’s degree requirements in educational leadership. Valerie was selected by her principal to participate in the MSP project because she was a teacher leader.

Data-Collection Methods

Focus group. Initial data were collected in a focus group setting. Focus groups allow for the collection of data through group interaction (Morgan, 1996). Four of the eight participants were able to take part in the focus group meeting, Alicia, David, Susan and Valerie. The Focus Group Protocol is in Appendix B. The focus group allowed participants to discuss changes they made in their practice since participating in the professional development project. Because 3 years had passed since the participants had been involved with the MSP project, the focus group setting allowed the participants to reacquaint themselves with the project and with each other. As the leader of the focus group, I had an active role in creating the group discussion. During the focus group I asked participants to describe their overall perceptions of the MSP project and to discuss two specific components, Lesson Study and the Best Practices for Teaching Mathematics course. I asked participants to describe changes they had made in their practice as a consequence of participation in the MSP project and followed up with a question on barriers that they had encountered.

Individual interviews. To complement the data collected in the focus group, interviews were conducted with the individual participants to explore specific opinions and ideas in more depth. Four participants were interviewed–Alicia, David, Susan and Jessica. A copy of the Interview Protocol is in Appendix C. During the individual interview, each participant viewed his/her last recorded teaching segment from the MSP project. After viewing the video, the participant was asked to reflect and comment on the classroom video segment comparing the teaching during the MSP project with current teaching practices. During the MSP project, participants used a video reflection tool as a guide for reflecting on their videos, so the interview questions in this study were designed similarly. The video reflection tool was based on the following questions:

1. Does classroom activity center on mathematical understanding, invention, and sense making by all students?
2. Is the lesson/task mathematically worthwhile for all students?
3. Is the classroom culture such that inquiry, wrong answers, personal challenge, collaboration, and disequilibrium provide opportunities for new learning by all students?

During the interview, the Personal Professional Timeline was gathered by asking each participant to describe the professional activities s/he had completed since the MSP project. Each participant was also asked to verify his/her certification history that had been compiled prior to the interview. A self-reflection survey focusing on four areas from the MSP project professional development activities was administered to participants at the conclusion of each interview. In the Teacher Reflection Tools Stages Survey, the participants indicated their stage of implementation with regard to the areas of understanding, culture, tasks, and content. (Appendix D)

Archived data. I used archived data from the MSP project to answer the research questions. During the MSP project, the full Learning Mathematics for Teaching (LMT) assessment had been administered to all participants annually for both years of the project. A summary of these scores was included in this study. The LMT was not readministered for this study. The LMT test authors recommend a sample size of at least 20; however, this study has fewer than 10 participants, and only 3 participants agreed to take the test again.

Survey data from the conclusion of the MSP project were also used in this study for comparison purposes. The survey responses are included in Appendix E. The open ended survey responses for the participants in this study are included along with the composite results of the entire MSP project group on the Likert scale statements.

The classroom videotaped segments from the MSP project were used to allow each participant an opportunity to reflect on his or her teaching during the project as part of the interview. Another archived data source was the District Instructional Practices Survey (see Appendix F). This survey was administered to middle school teachers in the district during the Fall of 2008. Forty-two of the district middle school teachers completed the survey, including four of the participants in this study–Daniel, Jessica, Susan, and Valerie. Table 4 lists the dates of the data sources that were used in this study.

Table 4.

Data Collection Timeline

Time	Event
Fall 2005	LMT pretest administered to the MSP project participants
Fall 2006 Spring 2007	Videotaping in MSP project participants' classrooms
May 2007	LMT posttest administered to the MSP project participants
Summer 2007	MSP evaluation interviews and surveys
Fall 2008	District Instructional Practices Survey administered to middle school teachers in district
January 2010	Focus group with study participants
January to February 2010	Individual interviews with study participants (including collection of Personal Professional Timeline and Teacher Reflection Tools Stages Survey)

Analysis

Using the coding process described by Auberbach and Silverstein (2003), I reviewed the data for relevant text and then looked for repeating ideas to develop themes from the text. Throughout the process, I continued to review and revise my coding system.

After transcribing each of the focus group and interview sessions, I began looking for ideas associated with the project. The first pass included ideas such as groupwork, worthwhile tasks, student-centered, discussion, and private think time. These ideas were then grouped into a theme of classroom practice. I then went back through the transcripts to further identify and differentiate between teacher actions and student actions that were described by the participants as part of their classroom practice.

The third area that I explored during the analysis of the data was the idea of participant self-reflection with regard to mathematical knowledge for teaching. I wanted to explore how they were attending to their own content development. The last area that I incorporated into the data analysis was the relationship between the data and my theoretical framework of transformative learning theory.

To keep the data organized during the coding process, I used a spreadsheet. Figure 3 gives an excerpt from the spreadsheet.

	Jessica	Susan	Alicia	Daniel	Valerie
CLASSROOM PRACTICES					
Private think time		I		I	
Worthwhile task	I	FG		I	
Manipulatives				I	
student-centered		I			
Discussion	I				FG
multiple representations		FG, I		I	

Figure 3. Coding sample from spreadsheet.
Note: I refers to the interview; FG refers to the focus group.

I used the spreadsheet to help identify common reoccurring themes from the focus group and the individual interviews. I linked the spreadsheet to actual participant quotes from the transcripts for reference during the analysis phase.

Limitations

One limitation of this study is the analysis of LMT assessment data based on the small sample size. I decided not to administer the LMT during this study because the small sample may have made it difficult to have a meaningful interpretation of the results. The small sample size was due to the transient nature of the school district where this study was conducted. The constant change in the teaching force in the school district may also have limitations on multi-year professional development projects such as the MSP project.

Although the MSP project evaluated the effects of the MSP project on student achievement, student data are not being included in this study because of changes in state testing that occurred following the completion of the MSP project. The state changed the reporting scale for the middle grades mathematics criterion referenced competency test (CRCT) and did not develop an equating scale for prior administrations.

Subjectivity Statement

In my dual role as a graduate student researcher and the mathematics coordinator for a public school system, I conducted research within the school district where I am currently employed. This situation provided me as the researcher with important contacts to assist me in gaining approval to conduct my study within the district. I also have established a professional relationship with the teachers who were part of this study. I have worked to create a relationship with the teachers based on mutual trust and respect. I think this relationship benefited the study because the teachers were open to sharing their thoughts about their instructional practices.

Miles and Huberman (1994) state, "Qualitative data masks a good deal of complexity requiring plenty of care and self awareness on the part of the researcher" (p. 10). I kept a journal during the data analysis phase of the study to identify through reflection and writing my thoughts about the professional development project and the participants so that I could become more aware of my opinions. I worked to incorporate researcher reflexivity by constantly questioning my assumptions about what I thought was happening (Creswell & Miller, 2000). I tried to maintain a heightened sense of awareness of the biases that I brought to the study and maintained this awareness when adding contextual data to observations transcriptions, interview transcriptions, and journal entries.

Peshkin (1988) defines subjectivity as "the quality of the investigator that affects the results of observational investigation" (p. 17). Peshkin points out that an individual's subjectivity is not something that can be removed, and it is therefore something researchers need to be aware of throughout the research process. It was important to examine my own subjectivities throughout the research process so that I would be aware of how these subjectivities could influence my interpretations and portrayal of events.

CHAPTER 4

DATA ANALYSIS

Assessing Mathematical Knowledge for Teaching

In this section, I present data on my first research question: How does participation in a mathematics professional development program support participating teachers' self-assessment of their mathematical knowledge for teaching? During the MSP project, the full Learning Mathematics for Teaching (LMT) assessment was administered three times beginning in Fall 2005. The administrations included Form B04 administered two times (Fall 2005 and May 2006) and Form A04 (May 2007). The equating tables provided by the test authors were used to generate the reported *z*-scores.

Table 5 provides a summary of the data. Growth of 0.30 or greater is generally considered to be significant; however, the low sample size for these results may have altered that threshold for significance. (The test authors recommend a sample size of at least 20). As shown in Table 5, there was significant growth in Algebra and Patterns between the initial pretest and the final assessment for the MSP project with the overall growth being 0.47 standard deviations for the overall group as well as the matched scores group.

Table 5

Algebra and Patterns Results

	Mean *z*-score	**Mean *z*-score matched***	
2005 pretest	-0.44 (n = 23)	-0.39 (n = 15)	
May 2006	-0.11 (*n* = 15)	-0.07 (*n* = 12)	
May 2007	0.03 (n = 18)	0.07 (n = 15)	0.08 (n = 12)

*The mean *z*-score when only the scores with a match in the final administration of the LMT are considered. For May 2007, the first score in the matched column is the mean as compared to the matched group from the pretest administration. The second score is the matched score as compared to the May 2006 administration.

The LMT assesses mathematics content and specialized content knowledge specific to teaching mathematics. Items in each category are designed to assess teachers' understanding of the mathematics problems they assign students, and also how teachers solve the special mathematical tasks that arise in teaching such as evaluating unusual solution methods, using mathematical definitions, representing mathematical content to students, and identifying adequate mathematical explanations (Hill, Schilling, & Ball, 2004)

Although I did not administer the LMT to the group again, I did use multiple measures to try to explore the participants' self-assessment of their mathematical knowledge for teaching. I reviewed the participants' professional histories after the end of the MSP project and also analyzed the participants' responses from the focus group and individual interviews, including the Teacher Reflection Tools Stages Survey that was completed as part of the interviews.

The certification history for each of the participants was gathered and analyzed along with the personal professional timeline that each participant completed during the interview. Teacher certification has been used as a proxy for teacher content knowledge in a number of studies. Darling-Hammond (2000) reviewed teacher qualifications, including certification data, from 50 states and concluded, “Teacher quality characteristics such as certification status and degree in the field to be taught are very significantly and positively correlated with student outcomes” (p. 23). State certification requirements differ around the country, but in Georgia there are several approved programs that lead to certification. The traditional route of completing a mathematics education program followed by a content knowledge assessment is required for certification in middle grades or secondary mathematics. Other alternative routes to obtaining certification exist; however, all candidates must pass the content knowledge assessment, known as the Georgia Assessments for the Certification of Educators (GACE) in the certification area.

Table 6 shows a summary of the participants’ education and certification. The first part of the table indicates the highest degree earned by the participants before the MSP project and 2 years after the project ended. At the time of the MSP project, all participants had middle grades mathematics certification. The second part of the table identifies additional certification of the participants before and 2 years after the MSP project.

Table 6

Participants' Education and Certification Summary

	2004	2009		2004	2009
Highest degree earned	No. of participants	No. of participants	Additional certification	No. of participants	No. of participants
Bachelor's	7	1	Early childhood mathematics Certification/endorsement	0	2
Master's	1	2	Secondary mathematics certification	0	2
Education specialist	0	5	Teacher support specialist	1	1

The data indicate that five of the eight participants in this study obtained additional degrees after the MSP project and two completed degree requirements during the MSP project. Daniel commented that during the project he decided to start his specialist program and was able to use some of the MSP courses as part of his degree requirements. He said, "The college math courses were very influential because I was able to collaborate with the college professors, and I could see what I am doing in middle school in the work in the college classroom" (Interview, January 20, 2010). Jessica started her specialist program after the MSP project. She corresponded with one of the graduate assistants that worked on the project to gain help with applying for the program and to ask general questions about requirements as she was making a decision about going to graduate school. Jessica completed her specialist degree in 2008 and shortly after also completed the requirements to add secondary mathematics to her middle grades certificate. Jessica was one of two participants who completed the requirements for secondary mathematics certification.

Susan was only in her first year of teaching when the MSP project started (Interview, January 27, 2010). During her interview, Susan talked about her undergraduate professors being a part of the MSP project: "You know a lot of it was my undergraduate professors. I had excellent mentors, and when we started the MSP, there they were with us so it was like 'I guess they were right, we should be doing this.'" Susan started her master's coursework during the MSP project and finished shortly after the project ended. She also added the early childhood mathematics endorsement to her certificate by taking additional coursework. The early childhood mathematics endorsement is a state-approved program in Georgia designed to strengthen the mathematics content knowledge of elementary teachers. The endorsement requires a minimum of twelve semester hours in mathematics content and pedagogical content knowledge in the strands of algebra, data analysis and probability, geometry, and number and operations.

Alicia commented during her interview, "The MSP allowed me to come into contact with and get to know people who had higher degrees and I thought … hmm, I think I can do that, and now I am thinking about possibly getting a doctorate." (Interview, January 29, 2010) Alicia completed her specialist degree requirements in 2009.

One participant, Edward, did not continue to pursue additional degrees; however, he did complete the requirements for the secondary mathematics certification in 2009. Edward had elementary, middle and high school certification and had taught at all three levels.

The MSP project focused on the content area of algebra for most of the project. At the end of the project, the participants were asked about the effect the MSP project had on their content knowledge. The MSP project teachers were very positive. On one Likert scale item prompting: “My involvement and participation in the MSP helped me improve my content knowledge,” the modal response was 2 (Agree). (see Appendix E)

Similarly, on a more recent survey of teacher practice that was administered by the school district to middle school mathematics teachers during the fall of 2008, responses from the MSP project participants were compared to the other middle school mathematics teachers in the district. Four participants from this study responded to the district survey. When asked about how prepared they feel to teach algebra, all four participants responded “very well prepared.” In comparison, only 36% of the district middle school mathematics teachers responded that they felt “very well prepared to teach algebra.”

To further explore the participants’ self-assessments of their mathematical knowledge for teaching, I asked each participant to complete a survey that had been part of the original MSP project. The questions were organized in four categories: (1) understanding, invention, sense making; (2) mathematical culture; (3) worthwhile mathematical tasks; and (4) mathematical knowledge for teaching. All of the survey questions were created through a classroom lens with a focus on students. In the MKT section, the questions focused on the relationship between a teacher’s content knowledge and teacher actions in the mathematics classroom. Appendix D shows the questions from the MKT section of the survey.

This aspect of MKT is referred to in the literature as teachers’ specialized content knowledge, mathematical knowledge needed to perform the recurrent tasks of teaching mathematics to students (Ball, Hill, & Bass, 2005). Because the questions had been introduced during the MSP project, all of the participants were familiar with them. Participants were asked to identify their current stage of implementation of each of the practices on the Teacher Reflection Tools (Foreman, 2003).

Jessica had recently changed teaching assignments going from eighth grade to seventh grade. When asked about changes in her practice since the MSP project, she commented, “I’m making a list of things I need to work on for the MK section because there are a lot of things I thought I knew but now I am wondering after I am teaching seventh grade.” (Interview, January 26, 2010) The participants’ willingness to reflect on their current understanding of mathematical ideas was also evident in the survey data. According to the Teacher Reflection Tools Stages Survey (Appendix D), one area that Jessica struggled with was considering student ideas as she asked questions in her classroom. Being able to incorporate student ideas into a lesson requires a teacher to have a deep understanding of the content that is being taught (Ball et al., 2005). Jessica talked a lot of about the grade change and her recent school change and wondered aloud during our interview if the move might have been a reason for her uncertainty about the content of her new grade level.

Alicia felt most challenged by providing access, engagement, and challenge for all students. She rated herself at Stage IV, regularly trying to provide access to the mathematics for all students in her classroom, but not seeing results yet and needing to learn more about this practice. In her interview, Alicia talked about trying to help students see relevance to the mathematics. She talked about how many of her students were disengaged not just with mathematics but also with school. Throughout her interview Alicia made comments about how she tried to find ways to relate mathematics to her students. Because she had been a high school mathematics teacher before moving to middle school, Alicia talked about the importance of knowing where the concept is going at the next level. She described this trajectory as planning with the end in mind and gave an example: "Thinking about teaching fractions in middle school and how that will lead to trig ratios later in high school" (Interview, January 29, 2010).

Interestingly, Jessica, Alicia, and Daniel all rated themselves at a Stage VI on the question, "Do I listen intently to my students' thinking and respond according to the mathematical validity of students' thinking?" This rating indicates that in this aspect of knowledge of content and student (KCT), the three participants were consistently listening to their students' mathematical thinking and making decisions based on this information.

Summary of MKT. All of the participants in this study continued to learn and grow as mathematics educators. Seven of the participants obtained additional degrees, four in areas that required at least one additional graduate level mathematics course and three in educational leadership. Two participants completed the requirements for the early childhood mathematics endorsement, and two completed the requirements for secondary mathematics certification. When teachers learn more about the mathematics taught in both the grade levels before and after the course they teach, it leads to a deeper understanding of mathematics. Understanding the trajectory of the mathematics supports an increase in horizon content knowledge, one of the seven components identified as part of MKT (Ball, Thames, & Phelps, 2008).

Participants discussed aspects of the MSP project that supported them in the area of mathematical knowledge for teaching, such as building relationships with higher education faculty and requiring content courses for all participants. The content courses not only increased the participants' common content knowledge in mathematics but also increased the participants' confidence in their understanding of mathematics, specifically in algebra. In addition, the MSP participants reported that they consistently listened to their students' mathematical thinking and responded based on the information.

MSP Project Influence on Classroom Practice

In this section I present findings related to my second research question about how participation in the MSP project influenced the participants' teaching practices. To answer this question I used archived MSP Evaluation Survey data, analysis of interview and focus group transcripts, and analysis of participant classroom video reflection from the interview.

Reflecting on practice. At the end of the MSP project, all participants responded to surveys regarding changes in their instructional practices. Overwhelmingly, the participants responded that they had become more reflective about their practices as a result of participation in the MSP project. Reflection is a personal process that enables the teacher to assess, understand, and learn through his or her experiences (Chapman, 2009). In the MSP project, teachers videotaped classroom episodes three to four times during the 2-year project and also participated in the lesson study sessions. Both of these experiences were included in the MSP project to support teacher reflection and to create a culture of reflective practice within the group.

One of the ideas I wanted to explore was the extent to which this idea of reflection was consistent in the participants' current teaching practice. Through reflection, teachers make sense of their experiences and then use this knowledge to inform future decisions (van Es & Sherin, 2008). All of the participants discussed the idea of reflecting on their practice at some point during the focus group or interview. In some cases the idea was brought up multiple times as participants tried to describe changes in their practice since the MSP project. I have organized the participants' reflections on their classroom practice into the following categories: supporting student thinking, using worthwhile mathematical tasks, and creating a mathematical classroom culture.

Supporting student thinking. During the summer institutes, the MSP project participants identified classroom practices that support student understanding, invention, and sense-making and reflected on their own practices with regard to these areas. Teachers who know about their students' mathematical thinking can support the development of mathematical understanding (Franke, Kazemi, & Battey, 2007). At the conclusion of the MSP project, survey data provided by teachers indicated that the teachers were better able to support student thinking by generating meaningful hands-on activities in their classrooms (see Appendix E). During his interview, Daniel brought up the use of manipulatives as one of his current practices. He said that he conducted interviews with students each year to get to know them better, and he found that many of his students have never used manipulatives before. He said that he tried to start off the year using manipulatives so students would get used to using them to help them understand the mathematics concepts in eighth grade. He especially liked to use algebra tiles and said, "Algebra is abstract and some eighth graders are just not ready for abstract, so the tiles give them the concrete so we can still work on the algebra problems while their thinking develops" (Interview, January 30, 2010). Jessica also used manipulatives with her students and used the term *student-centered* to describe her classroom. She reported that in a recent lesson, her students had used two-color counters to learn about integer operations. She said that before the MSP project, "I was pretty much teaching as I had been taught, which was pretty much old school. After the Best Practices course I was willing to try some things." (Interview, January 26, 2010) She said that she tried to let the students be more independent, and her instruction was more focused on their understanding so they do most of the work.

In contrast, Susan described her teaching at the beginning of this year as more teacher centered since she had moved back to eighth grade. She said, "I just wasn't confident, so I could feel myself going backwards. My eighth-grade colleague was giving me these worksheets. And she said she used them last year, and her CRCT scores were so good. So I just wanted to follow her lead since I had been out of middle school for a while" (Interview, January 27, 2010) . Susan then described how she had decided to make a change and break away from her colleague's lessons. "You know you have to know your students, and I was just not getting anything from the worksheets, so I just decided to do my own thing. I just can't be that teacher centered in my classroom. It just doesn't work for me." While in her classroom for the interview, I noticed student work on the walls from an introductory lesson on functions, so I asked her about the assignment. She said her students had listed qualities about themselves like name, pets, and number of siblings and then had put the qualities together to create relations. She had used this activity to emphasize the properties of the domain in a functional relationship. She said, "It was cool because they had to think about it when more than one person had the same name or the same number of siblings, and when I did the ticket out the door yesterday, 95% got it correct."

The actions described by the participants in this section support the notion that the participants were working to foster student thinking in their classrooms. On the Teacher Reflection Tools Stages Survey, Alicia and Daniel identified themselves at Stage VI, and Jessica identified herself at Stage V on implementing private think time for students. Private think time supports students' thinking by making time for the act of thinking and acknowledging that each student's ideas are important. Jessica indicated that last year she was at Stage VI in this area; however, this year she identified time as a constraint for implementing private think time consistently in her classroom. She said that sometimes with her new grade level curriculum, she was not confident and was not able to judge the time it took for students to work through the lesson she designed.

Using worthwhile mathematical tasks. Worthwhile tasks were defined in the MSP project summer institute as tasks that engage students in thinking and reasoning about important mathematical ideas. Worthwhile tasks can be solved in multiple ways, involve multiple representations and require students to justify, conjecture and interpret (Stein, Smith, Hennigson, & Silver, 2000). During the focus group, Susan discussed the idea of finding worthwhile tasks to have students work on in class. She talked about a recent lesson that she taught in her class where students completed a project, but as she started sharing, she stopped and said, "Actually I was just thinking about the project I had my kids do and the things we learned in the Designing Groupwork course. And I realize that was not really a good project. … There's really only one solution, and there are not multiple representations. I guess it [the Designing Groupwork course] was really good because I am reflecting now."

Jessica commented in her interview that it had been much easier for her to do the tasks after the state had adopted the new Georgia Performance Standards (GPS). "I think I was trying to do the tasks back then, but since we got into the GPS, it's a lot easier to do it now. I don't use my book much, actually; I just told them to leave their books at home" (Interview, January 26, 2010). Jessica said that she had been designing tasks and rubrics for students to do as part of each unit she taught. In our interview, she described the process she went through to decide if the task suggested by the state was really worthwhile and got at the mathematics standard she was teaching. This process is where she said she was spending most of her time because she had moved to a new grade level. She had also designed a website to share the resources she created with her students, their parents, and other teachers. In one of the tasks that she talked about during her interview, students had to show their understanding of the relationship between two variables in an algebraic equation. She had the students do the stacking cups problem. Given a set of identical paper cups, students had to represent the relationship between the number of cups in a stack and the height of the stack using a table, a coordinate graph, a formula, and a written description. She asked students to discuss the advantage or disadvantage of each representation in this situation.

Susan was also teaching in a new grade level. At the time of the MSP project, she had been teaching eighth grade, and shortly after the project ended she moved to fifth grade. At the time of the study, it was her first year back in eighth grade. In our interview, Susan said that trying to find worthwhile tasks was still hard for her. She described the resources that she was using as having only one way to solve a problem, so most times she had to look through multiple resources to find good tasks. Susan shared a recent classroom experience: “I just had my students do this Venn diagram task, and after looking at their work, I felt it wasn’t such a worthwhile task after all even though I had used a graphic organizer. So I was really disappointed” (Interview, January 27, 2010).

Daniel was very confident in the changes that he has experienced in his classroom teaching practices. In the interview, he said,

> I can remember in my early years that I always thought I was doing the best activity with my students, and I remember thinking about some of those tasks after we took Best Practices and thinking this really was not worthwhile; it wasn’t correlated to what I was teaching. Did they learn something? Yes. Did they enjoy it? Yes. But it wasn’t necessarily connected to the standards. If there is a project that I am doing now, it goes back to what we are learning in the standards.

In the MSP project, the Mathematical Task Framework (Appendix G) was introduced and used throughout the project to analyze lessons. The Mathematical Task Framework describes the phases through which tasks pass as they are implemented in a mathematics classroom (Stein et al., 2000). Although the participants were familiar with the framework, they did not use terms such as *low* or *high cognitive demand* to describe the tasks used in their classrooms. Task demand was an area that the participants seemed to still be struggling to understand and implement in their practice.

Creating a mathematical classroom culture. During the interviews, the participants described their current classrooms. All of the participants discussed their intent to create a classroom culture that centered on students and supported student thinking. As I reviewed the transcripts, I realized the participants were not just talking about the social norms in their classroom but the sociomathematical norms. Yackel and Cobb (1996) described sociomathematical norms as specific to the mathematical aspects of student activity. A section of the Teacher Reflection Tools Stages Survey contained questions related to classroom culture. (Appendix D)

Daniel rated himself at Stage V on most of the questions. Daniel seemed confident about his current classroom practices in this area. During the interview, Daniel talked about the need for consistency with his response to questions so that he did not just divulge the answer and stop the thinking his students were doing. He described his classroom as a place where students had to explain their mathematical thinking and reasoning not just to him but to each other. He said using "private think time" allowed everyone to get their thoughts together before he let them move on. He continued by saying that he sometimes asked students to share with their partner before the whole group discussion to give them a chance to try out their thinking. He commented, "I am just amazed at what they come up with each year. I think it is important for us to have respect for each other and others' thinking."

To develop a classroom culture where students respect one another, Jessica had allowed her students to create community agreements. She described her process for working with her students to develop the agreements at the beginning of the year. She said that she started by asking the students to think privately about things that were important to help them learn in class. After they had a chance to write a few things down, she asked them to work in a small group to share their ideas and decide on two ideas that would be shared with the class. As each group shared their ideas, other groups with similar ideas would share theirs until all ideas had been shared. She said she gave everyone a chance to add or take away something that they felt was important. Jessica used the community agreement idea to show respect for her students and to help build a classroom culture that allowed students to share their mathematics thinking. The community agreements for each class she taught were listed on the class website and were also posted in her classroom. An example of one of her class's community agreements is listed in Figure 4.

Community Agreements for Periods 13-14	
Teamwork Don't exclude anyone from the group Study & share thoughts with others Work together Respect Be respectful to others Obey the teacher	Pay attention to the teacher Don't be disruptive Don't act negatively Study hard Study study study study study Work hard

Figure 4. Example of Jessica's class-created community agreement.

In her Teacher Reflection Tools Stages Survey, Jessica indicated that she was at Stage IV with regard to three of the survey questions:

> 2. Do students rely on their own thinking and the mathematical logic and structure of ideas to judge the correctness/usefulness of the ideas (or do they defer to others for authority based on personalities or roles)?
>
> 4. Are "we wonder…." "we think…" and "we predict…" statements about relevant mathematical ideas central to collaborative investigations?
>
> 9. Are students equitable in their spoken and unspoken messages about all students' mathematical potential?
>
> (Foreman, 2003, p. 43)

In reflecting on the description of Stage IV, Jessica attributed her regression in these areas to her transition to her new school. Jessica's new school was a fine arts magnet school that required students to audition and maintain a high level of academic success. Students not meeting the academic standard were required to leave the school and return to their zoned school. In her interview Jessica said that she had noticed that her students seemed to have a hierarchy created that had been complicated to dismantle.

The hierarchy consisted of some students labeled by peers as smart and others as artistic, and not many students fell into the category of both smart and artistic. After realizing this labeling, she said she decided to change some of the assignments she was giving her students. A recent assignment allowed students to show their understanding of geometric transformations in a variety of ways. One student not normally characterized as smart in mathematics choreographed and performed a dance that showed all of the geometric transformations that had been assigned including a stage sketch describing the relationship between the coordinate plane and the performing stage. Jessica said focusing on individual student strengths and assigning work to complement their strengths was something that she had learned in the MSP project summer institutes. She said the idea of changing the students' perception of who is smart was something she was trying to work on. She commented, "I'm trying to work on building the community in our classroom and also making each child speak up a little bit more."

Susan also discussed her classroom culture in the interview. She commented that she let her students know that learning causes disequilibrium so that they knew it was "ok to be in disequilibrium and to be confused." As she continued to talk about her classroom, Susan discussed using private think time as a way to allow students time to think before having to share with others. She gave mixed information on her use of that strategy in her classroom. After my interview with Susan, I wrote the following in my journal,

> The discussion today with Susan made me wonder if the interview itself might have been an opportunity to sit down and think in what seems like such a busy day-to-day routine. I think her use of private think time will increase based on the way she talked herself through that idea today during the interview. She started by saying it was something she was still using and then went on to say that she had not been as consistent with that

> idea since about October when things got so busy. She followed up later in the interview by saying she was going to work on the private think time idea again by adding that back to her routines and rituals. I guess it is possible to have influenced her practice by just having the interview today.

Alicia described her classroom culture as just being a reflection of who she is as a person. She said that she had just moved from high school to middle school when the MSP project started, so she was really surprised at the negative feelings her students had for mathematics. She said she remembered trying to find ways for her students to be successful and started trying to create analogies to connect the mathematics to her students' lives. She said,

> I look at the standard, and then I try to find something that relates to it … anything. Like one time I explained the distributive property using candy bars, you know. I said the classroom was like the parenthesis, and the teacher was like the number outside the parenthesis, and each student was like the number in the parenthesis. Nobody wants to get left out, so the teacher gives a candy bar to everyone. They really remembered that. We used to call the distributive property the candy bar property.

Alicia described her classroom as a place to practice, and she said that she tried to explain to students that it was all right to get a problem wrong; it just meant you needed to find out why and start again. She talked about individual students that she had worked with as a middle school teacher that she continued to work with as a high school mathematics coach. She said, "I love my students, and I want them to experience success. That's just something you can't hide. Your class culture is just who you are" (Interview, January 29, 2010).

Summary of influence on classroom practice. The actions described by the participants in this section support the notion that they were working to foster student thinking in their classrooms. They described their current teaching practices as student-centered and focused on helping students understand mathematics. One practice discussed by the participants was the use of manipulatives to help build understanding of mathematics concepts for students. At the conclusion of the MSP project, teachers indicated that they were better able to support student thinking by generating meaningful hands-on activities in their classrooms, and the participants in this study continued this practice even after the end of the MSP project.

Building relationships with students is critical to the success of developing classroom norms that support the development of mathematical understanding (Franke, Kazemi, & Battey, 2007). In a classroom setting, sociomathematical norms evolve and become more well-defined through ongoing interactions between the students and teacher (Yackel & Cobb, 1996). All of the participants in this study seemed to know their students and had created classroom cultures where students could develop mathematical understanding.

Based on the participants' responses to the Teacher Reflection Tools Stages Survey in each of the categories associated with classroom practice, and based on the interview and focus group data, I conclude that movement through the stages is not always in a constant forward direction. As conflicts such as time constraints, a change in teaching assignments, or new curriculum resources are encountered, teachers must make decisions that sometimes contradict their teaching goals and move them backward through the stages.

Collaboration Patterns

To answer my third question about the participants' collaboration patterns, I searched through both the focus group transcripts and the interview transcripts to find references to collaboration. During the individual interviews, I asked participants to describe their definition of *collaboration*. All of the participants had similar elements in their definitions. Those elements included working together, planning together, trusting the group, and respecting each other. Alicia even personalized her example by using the analogy of collaboration being like a marriage. She said, "It's almost like a marriage. I have to respect you as a person and as a teacher and as a contributing body to this collaboration. I have to know and trust that you have something to bring to the table." I wanted to understand the ways these participants worked with others and reflected on their teaching because "without the medium of relationships, reflection can take the genuine discourse necessary for thoughtful and in-depth changed in behavior" (Chapman, 2009, p. 126).

I tried to apply the PRISM Learning Community Rubric to the group to gather more information about the groups' collaboration patterns. The PRISM Learning Community Rubric contains five indicators that can be used to evaluate the level of implementation of a professional learning community. The rubric was designed to be used with a P–16 project like the MSP project; however, the small size of the group and the lack of higher education participants in this study narrowed the indicators that were applicable for this study. Two of the indicators that I discuss in this section are shared vision and collaborative inquiry from the PRISM Learning Community Rubric (Appendix A).

To provide information about shared vision, the participants responded to statements about collaboration during the interview using a Likert scale, with 1 being strongly disagree, and 4 being strongly agree. The statements are listed below:

I feel supported by colleagues to try out new ideas in teaching mathematics.

Mathematics teachers in my school have a shared vision of effective mathematics instruction.

Participant responses indicate that the collaboration of individual members of the group with their school-based colleagues was inconsistent. In Table 7, the participants' responses to the collaboration statements indicate that two felt they had support at school, whereas two disagreed strongly that they were supported.

Table 7

Summary of Collaboration Responses

Indicator	Responses			
	Alicia	Daniel	Jessica	Susan
Support	3	1	4	1
Shared vision	3	1	3	3

These statements were designed to provide data on the extent to which MSP participants had been able to influence their school-based colleagues. In the interviews, I asked participants to expand on their scaled response to each of the statements. Susan discussed the need for more time to work with her colleagues. Susan was in a newly opened school so all of the teachers were getting to know each other, and she described this experience as "just feeling overwhelmed" (Interview, January 27, 2010). She was "searching for a colleague who really knows math to help me plan and think about what we need to do. I don't have that yet."

Daniel discussed the changes in administration at his school over the past ten years and described the lack of support and vision at his school in connection with administrator changes. He said his colleagues are very supportive of him trying new things but they are not as eager to do it themselves. Daniel shared that his new administrator may be helping by making the mathematics teachers meet together every week. He said, "At first I didn't like having to meet with everyone because they didn't seem to have any ideas to share, but now it's getting better. I think my principal is probably trying to support us, but we have some bad habits and some old school teachers she is having to deal with" (Interview, January 30, 2010). I probed Daniel to further discuss the bad habits, and he shared that he had not really had a chance to get to know everyone that teaches mathematics in his building because his last principal was constantly changing teacher assignments and room locations. He said that people just stopped talking and sharing.

In her new role as instructional coach Alicia discussed her struggles in trying to build a collaborative community with her teachers. She described the mathematics department as having a shared vision and being supportive of each other, but she was still struggling with the new administrative team's vision for the school. She commented that communication was the most difficult part of building the community because the administrative team made changes constantly, and it was hard to keep her teachers informed.

Jessica commented that she thought it might be difficult to move to a new school and continue to have the collaborative experience that she had grown to expect at her former school. At her former school she met daily with her grade level mathematics colleagues. She said, "We met regularly, but we would always share during the day about how kids were responding to the lesson that we had planned. I was worried that I wouldn't have that level of support here" (Interview, January 26, 2010). She said that she was surprised when her new department started meeting. "Because we are 6^{th} – 12^{th} grade, the discussions are so different. We are analyzing the middle school math scores to talk about what we can do. The 8^{th} grade teacher said probability was their hardest part, but I love teaching that so as soon as we finish testing I'm going to go ahead and start teaching probability in 7^{th} grade so they will be ready" (Interview, January 26, 2010). Jessica summarized by saying that even though the teachers in her school teach different grade levels they teach the same students so that keeps the department connected.

I used the PRISM Learning Community Rubric to identify the level of implementation of each participant's school community based on data collected through the interview. Jessica was in a school that would be categorized as developing, Alicia was in an emerging school, and Daniel and Sally's schools were categorized as beginning with relation to the indicator of shared vision. The inconsistency of these data indicated that collaboration outside of the MSP project group had not developed as a result of the project. Another theme that started to emerge from the interviews was the effect of the administration on the professional learning community in a building. The participants' perceptions of their administrators and colleagues varied from person to person and school to school, and the feeling of collegiality described by participants in reference to their MSP project experience had not transferred to their school-based professional learning communities.

On the topic of collaborative inquiry, the data shifted. The participants were considered the professional learning community on this indicator. The participants had the opportunity to take part in the lesson study process during the MSP project. Loucks-Horsley, Love, Stiles, Mundry, and Hewson (2003) described the key elements of lesson study:

> Teachers collaborate on the development and refinement of lessons.
> The results of lesson study benefit all teachers and students.
> The focus of the lesson studied and researched is directly related to standards and school goals.
> Critical feedback is on the effectiveness of the lesson and not the teachers' performance while teaching.
> Enhancing teacher and student learning is grounded in practice.
> There is a structured process for guiding the lesson study. (p. 185)

Consistent practice of all of these elements would be categorized as *accomplished* in the collaborative inquiry indicator of the PRISM Learning Community Rubric. During the focus group session, the participants were asked about the lesson study process. Each participant commented on the important aspects of lesson study.

Alicia: The concept of lesson study still fascinates me. The idea that the focus was not on how you do something but how kids respond. … I still want to incorporate it into what I am doing, like, as a coach. It takes away all the arguments about why other things can't work. It's about reflecting and how things affect kids.

Susan: I got a lot of things from lesson study, like when we saw Jessica teach. I learned a lot like questioning and how to respond to student questions.

Valerie: I enjoyed the lesson study because it was a chance to go into real classrooms. I always came out learning something. I think the biggest thing that came out of this was the time after the visit when we reflected on what we had seen. It opened up my eyes a little bit more. … It was good to see some of the students struggle so we could think together as a group about what should be the teacher's next move.

Daniel: It was an opportunity for professionals to persuade other professionals to think about our practice. I think it was very humanizing to focus on one or two things because when I am in my class and I have all these students, there is no way I can effectively know what everyone is doing. It's unfortunate that I don't have all that information on every student like we collected during each lesson study session.

Based on the participants' comments, the lesson study process encouraged collaborative inquiry at the highest level of implementation. As a group, the participants in this study engaged in a collaborative cycle of inquiry, reflection, analysis, and action through the lesson study process. The professional development that the participants experienced allowed them to collect data on student learning and to reflect systematically on the process. Using the PRISM Learning Community Rubric, the participants were identified as *developing* in the topic of collaborative inquiry.

As a part of the lesson study process, lessons and materials were developed and shared between the MSP project participants. When asked in the interviews about sharing ideas and materials with colleagues, the participants overwhelmingly agreed that this sharingwas part of their current practice. In fact, the same statement had been part of the district Instructional Practices Survey in 2008, so I decided to compare the responses of the MSP project participants with those of the other district middle school mathematics teachers on the statement, "Mathematics teachers in my school regularly share ideas and materials related to mathematics." On a scale of 1 to 4, with 1 being strongly disagree, and 4 being strongly agree, the MSP project participants had an average rating of 3.25 on this statement, whereas the average district response was 2.9.

During the interviews, several participants said they were still sharing with members of the MSP project. Jessica commented on how she shares lesson plans with teachers from her previous school and with teachers from the MSP project through email and also her class website.

Valerie had commented during the focus group session that the MSP project had given her the opportunity to open up. She said, "Visiting other teachers' classrooms gave me a chance to see how other people teach, and the group supported me when I decided to try new things. It helped me change instead of just choosing to do the same old thing" (Focus group, January 20, 2010). Daniel thought that the most important part of the MSP project was being able to come together with other professionals to think about teaching. Alicia expanded on this idea in the focus group session, saying, "It was the collegiality, to be able to be around people who want to perfect their craft, that's what made it important for me" (Focus group, January 20, 2010).

Summary of collaboration patterns. The MSP project set up a structure for participants to collaborate. Just as putting students in desks side by side does not ensure productive groupwork is taking place, the same is true for teachers. Although teachers may be members of the same department or school, that does not mean that they are collaborating with each other. The protocols that were used throughout the project to try to create equitable sharing created the norms for the group that were still in place.

The MSP project participants consistently referred to sharing ideas or materials throughout the interviews and focus group session. Actually, the focus group session was the first time some of the participants had seen each other during the school year. They seemed genuinely happy to see each other and continued talking with each other for at least 20 minutes after the session ended. They talked about what they were teaching, the instructional materials they were using, and how students were doing on the tasks. This impromptu sharing session is evidence supporting the collaborative culture of the community that was created through the MSP project that still remained even after 3 years.

Conclusion

The participants in this study continued to grow and learn even after the MSP project. They continued to seek additional degrees and certification. During the MSP project, they completed mathematics content courses taught by higher education faculty. They listed the relationships formed with the higher education faculty members as one of the aspects of the MSP project that supported the development of their mathematical content knowledge. The participants indicated that they felt prepared to teach algebra and as a group were more confident than other middle school mathematics teachers in the district based on a district survey of instructional practices. The participants reported that they consistently listened to their students' mathematical thinking and responded based on the information.

Through the Teacher Reflection Tools Stages Survey, data were collected on the participants' classroom practices. The participants described wanting their classrooms to be student centered but varied in their implementation and consistent use of the practices supporting a student-centered classroom. For each participant, the change process was different. One practice that seemed consistent for the participants was the use of manipulatives to support student understanding of mathematics concepts. Another practice that was common for the participants was the use of "private think time" as a strategy for engaging students in the process of thinking about the mathematics in a task. This practice was identified by all of the participants as important; however, it was not consistently used by all of them. The main reason given by the participants for the inconsistency was the time constraint in daily teaching.

During the MSP project, the participants had used the Mathematical Task Framework to analyze lessons and had developed a shared meaning of the term *worthwhile mathematical task* (Stein et al., 2000). The data indicate that the participants were able to discuss worthwhile mathematical tasks, but they seemed to move back and forth with relation to their classroom practice with such tasks. The participants were clearly struggling to implement such tasks in their practice.

The MSP project set up a structure for the participants to collaborate and form a professional learning community. The lesson study process encouraged collaborative inquiry and through the professional development that the participants experienced they learned to collect data on student learning and to reflect systematically on the process. The participants consistently referred to sharing ideas or materials throughout the interviews and focus group session. Unfortunately, collaboration with school-based colleagues not participating in the MSP project was not evident. It does not seem that individual members of the MSP project's professional learning community were able to influence those outside the community.

CHAPTER 5

CONCLUSIONS

Summary

The purpose of this study was to explore classroom practices and collaboration patterns of middle school teachers 3 years after their participation in a professional learning project focused on student thinking on the topic of algebra. Research is needed to help teacher educators better understand how professional development influences the work of mathematics teachers over time. This study provides the research community with an inside look at teachers' perspectives on the issues surrounding incorporating research findings on best practices in teaching mathematics into their planning and lesson implementation.

This study was a follow up to a Mathematics and Science Partnership (MSP) project. The MSP project partnered the school district with two higher education institutions with a goal of making a significant impact on the teaching of mathematics and science. During the 2-year project, teachers participated in content-development courses, engaged in reflection on their teaching, and created communities of learners within and between their schools. Each year of the project, the teachers participated in a 2-week summer institute and monthly study group and lesson study sessions. In this study, I investigated the following research questions:

1. How does participation in a mathematics professional development program support participating teachers' self-assessment of their mathematical knowledge for teaching?
2. How do teachers think their participation in a mathematics professional development program focusing on student thinking has influenced their mathematics teaching?
3. What perceived changes occur in participating teachers' patterns of collaboration with colleagues during and after the professional development program?

Because this study followed participants after the end of the MSP project, it provides insight into the elements of the professional development project that were sustained in teacher practice over time.

The sample for this study was middle school mathematics teachers in a Georgia public school district that partipated in the district's Mathematics and Science Partnership (MSP) professional development activities from 2005 through 2007. Of the original 24 mathematics participants, 8 were still working in the district and also had archived videotapes from the project. Five participated in this study, and archived data were used from all 8 participants.

In this qualitative study, I used a focus group and individual interviews as methods for collecting data. Because 3 years had passed since the participants had been involved with the MSP project, the focus group allowed them to reaquaint themselves with the project and with each other. In the individual interviews, participants were asked to reflect and comment on their current classroom instructional practices. They were asked to provide a history of their professional learning experiences since the MSP project and to determine their current level of implementation of each of the practices that was identified in the MSP project as best practices for teaching mathematics.

The archived data that were used included results from the Learning Mathematics for Teaching (LMT) assessment that had been administered to all MSP project participants annually for both years of the project. The archived data also included the survey data collected at the end of the MSP project. In addition, the classroom videotaped segments from the MSP project were used to allow the participants an opportunity to reflect on their teaching during the project as a part of the interviews. Results from a survey of instructional practices that was administered to all middle school teachers in the district in 2008 were also used.

To answer the first question on teachers' self-assessment of their mathematical knowledge for teaching, I used multiple measures. I reviewed participants' professional histories since the end of the MSP project and also analyzed their responses from the focus group and individual interviews, including the Teacher Reflection Tools Stages Survey that was completed as part of the interviews. The participants continued to assess their own mathematical knowledge for teaching and designed their own professional learning paths after the MSP project ended. They were confident about their understanding of algebra. Two participants who had changed grade levels since the end of the MSP project identified areas of mathematics such as geometry that they wanted to learn more about in the future.

The second research question was about how participation in the MSP project influenced the participants' current teaching practices. To answer it, I used archived

MSP Evaluation Survey data and analyzed the data collected during the focus group and the interviews, including the Teacher Reflection Tools Stages Survey. I organized the participants' reflections on their classroom practice into three categories: supporting student thinking, using worthwhile tasks, and creating a mathematical classroom culture. The participants shared changes that had occurred in their practice over time, comparing their teaching before the MSP project to their practices at the time of the interview. I used the Stages of Teaching in Transformation framework (Foreman, 2003) to analyze the participants' responses. The participants all agreed that supporting student thinking was important to them in their classrooms; however, they were at different stages of implementation of the practices that had been introduced during the MSP project. The use of manipulatives was one of the most consistent practices identified as being part of their current classroom practices. The practice of using worthwhile mathematical tasks was being inconsistently implemented by the participants. The data indicate that they were able to discuss worthwhile mathematical tasks but were clearly struggling to implement such tasks in their current practice; however, each participant had built relationships with their students and created a classroom culture that supported student mathematical understanding.

To answer the third question about the participants' collaboration patterns, I searched through both the focus group transcripts and the interview transcripts to find references to collaboration. In addition, I compared the responses of the MSP project participants including the participants in this study with those of the district middle school mathematics teachers using archived data from the District's Instructional Practices Survey. I used the PRISM Learning Community Rubric to determine the level of implementation of two categories: shared vision and collaborative inquiry. To report on the level of shared vision present at each participant's school, I used the rubric and interview data. I then analyzed the focus group data to determine the level of collaborative inquiry between the participants as a group. Participant responses indicate that the collaboration of individual members of the group with their school-based colleagues was inconsistent; however, the MSP project group was considered to be a "developing" professional learning community.

Conclusions

The partnership between the higher education institutions and the school district in this study supported the development of the participants' mathematical knowledge for teaching. The participants reported confidence in their understanding of mathematics, specifically in algebra. Compared with other middle school teachers in the district, the participants thought they were more prepared to teach algebra. The comparison was based on responses to a survey on instructional practices that was administered to all middle school teachers in the district in 2008.

The participants commented on the importance of building relationships with the higher education faculty members that had been part of the project. Some attributed the reason they continued with graduate studies to the encouragement and support they received from the higher education faculty members. Seven of the participants obtained additional degrees after the MSP project began. Four of the seven degrees required at least one additional graduate level mathematics course, and the other three degrees were in educational leadership. In addition, two of the participants completed the requirements for the state early childhood mathematics endorsement, and two added secondary mathematics to their certification.

The participants in this study continued to grow and learn beyond the MSP project. They continued reflecting on their own practice and learning from the situations within their classrooms. This type of learning can be described as generative learning. For the MSP project participants in this study, learning had become self-generating as the teachers were continually adding to their understanding (Franke, Carpenter, Levi, & Fennema, 2001).

The MSP project influenced each of the participants in this study. At the time of the study, the participants were at different stages of implementing the practices learned during the MSP project. They noticed changes in their own practice and identified specific practices that they used regularly in their classroom. The Stages of Teaching in Transformation framework provided a way for them to identify their implementation level on each of the practices and also supported the notion that changing instructional practices can be a cyclical process. In the Stages of Teaching in Transformation framework, a teacher can be moving forward through the stages when something causes a setback or slide. In this study, two participants openly discussed their setbacks and possible causes for the regression; however, both seemed relieved to be reminded of the stages that had been discussed throughout the MSP project. Challenges such as time constraints, new teaching assignments and new colleagues had led both back to some of their old practices. One even described herself as "going backwards" to being teacher-centered, and when describing her struggles with teaching her new grade level, the other physically made a circle in the air with her finger to describe her movement through the stages.

The MSP project provided the participants with a common set of experiences that encouraged classroom practices that were student centered and focused on student thinking. Participating in the lesson study process gave the participants an opportunity to observe the student-centered classroom practices in action, to collect data on how students responded to the lesson they had developed, and then to make changes to the lesson with a group of colleagues before they had to try it for themselves. This scaffolded approach to professional development began to change the habits of mind of the participants. For three of the participants, Alicia, David, and Jessica, the change in their practice began because of a specific event during the MSP project, whereas for Sally and Valerie the change had been gradual after the project ended. All of the participants made some changes in their practice toward the practices encouraged in the MSP project. At the end of the MSP project, the participants overwhelmingly responded that they had become more reflective about their practices as a result of participating in the MSP project. In this study, the participants reflected on their classroom practices, describing ways that they supported student thinking, used worthwhile mathematical tasks, and worked to create a classroom culture that supported student thinking. The participants continued to look at their classrooms through a student lens and built relationships with students in an attempt to understand student thinking.

The participants in this study engaged in a collaborative cycle through the lesson study process during the MSP project. A structure utilizing protocols was included in the MSP project to develop and encourage participant collaboration. On the indicator of collaborative inquiry using the PRISM Learning Community Rubric, the group was categorized as *developing* at the time of the MSP project. As a result of the MSP project experiences, the participants continued to share ideas and materials after the end of the project. Sarason (1996) suggested that a key to supporting teachers' ongoing growth is creating a school culture where serious discussions of educational issues occur regularly and where teachers' professional communities become productive places for teacher learning. The participants in this study no longer had a consistent professional learning community structure in their individual schools. Unfortunately, collaboration with school-based colleagues not participating in the MSP project was not evident.

Implications

Understanding the work of teaching is complicated, and trying to assess all of the aspects of mathematical knowledge for teaching is difficult. The mathematics education community needs a variety of ways to assess teachers' mathematical knowledge for teaching, including self-assessment rubrics. In this study, I analyzed participants' professional histories after the end of the MSP project, including certification. I also asked the participants to assess their own development in mathematical content knowledge with questions focused on classroom practice. It is important for teachers to become reflective and cognizant about their own content knowledge in order to support the development of their students' content knowledge in mathematics.

Professional developers should be straightforward with participants about the research on the change process and provide them with a framework for assessing their own growth and development. Often participants in professional development feel overwhelmed when faced with making changes in their practice, and challenges such as time, unfamiliar content, reluctant students, doubting colleagues, and standardized tests can cause them to reject the new information learned. For the participants in this study, the process of reflection became more consistent in their practice over time. The Stages of Teaching in Transformation framework (Foreman, 2003) provided them with a model that supported the notion that they may have challenges during implementation of a practice and gave them a sense of reassurance and the confidence to continue working on their practice.

This study supports the recommendations in the research literature that professional development projects must be long term and should be designed to support participants at varying stages throughout the project (Sowder, 2007). The MSP project in this study was a 2-year professional development project. After the project funding ended, the structured meetings, including the lesson study sessions, were not continued, and the participants were left to organize their own meetings or sharing sessions. The professional learning communities at each of the participants' schools were not fully established, so support from colleagues in their own building varied. Loucks-Horsely et al. (2003) suggested that it can take several years for teachers to fully implement a new practice, so some structure for continued collaboration should be established to support teachers at the various stages of the cycle throughout their careers. The findings of this study support that claim.

The MSP project design brought teachers from different schools together to build a professional learning community. The participants in this study experienced the support from the professional learning community but had not been able to consistently establish a professional learning community within their own schools. The transient nature of the school district and the participants in this study indicate that teachers in the district continually have to rebuild their community due to personnel changes and changes in building leadership.

Future Research

Further analysis of the participants' current practices could be established through the use of video reflection. Much like the original MSP project, participants could videotape a classroom episode and use the video reflection tool questions to mark evidence supporting implementation of specific strategies used in their practice. The analysis of those data could be combined with the self-reported data gathered through this study to strengthen the conclusions.

It would be interesting to explore the participants' understanding of algebra as an extension of this study. During the MSP project, participants focused on the concept of algebra and how best to teach algebraic concepts, so it would be helpful to expand this study to gather and analyze the participants' current thinking on algebra and the types of lessons they use in their classroom.

Another extension of this study could be to analyze the connection between the professional development project and student learning. In the original MSP project, this analysis was completed; however, because of changes in state testing in Georgia a comparison between the groups was difficult. Now that the Georgia Performance Standards (GPS) have been rolled out to all middle grades, a comparison between the group of MSP project participants and those not participating could be conducted.

The mathematics education community needs a variety of ways to assess teachers' mathematical knowledge for teaching. Because the concept of MKT is still developing, deciding what to assess has been one of the most challenging aspects of designing an assessment. Some assessments are currently available; however, more research is needed on MKT, including rubrics that teachers can use to self-assess their level of MKT related to the grade level they teach or a specific strand of mathematics.

Final Thoughts

This study provides the mathematics education community with an inside look at teachers' perspectives on the issues surrounding incorporating research findings on best practices in teaching mathematics into their planning and lesson implementation. This study was a reflective process for me also and altered some of my beliefs about professional development design and the process of change. The overarching conclusion that emerged from this study for me is that professional development projects must be designed to support teacher learning over time. In this study the data indicate that the participants continued to develop, grow and reflect on their teaching practices after the MSP project, and I attribute this to the design of the MSP project. The project design scaffolded the new learning with actual classroom practice during the lesson study cycles so teachers were able to work on the work of teaching during the professional development.

The MSP project design established a partnership with higher education faculty that supported the participants' continued increase in attention to their mathematical knowledge for teaching; however, some practices such as building community did not appear to have as strong a continuation, possibly due to the transient nature of the district.

The transitions from grade level changes to administrative changes led teachers to have to rebuild their community, so the participants did not consistently experience support for the changes they were making in their practice.

Teachers will never be “finished” working on their practice. As growth and learning continue in different aspects of a teacher’s complicated world, there is constant movement through the stages with both forward and backward motion as teachers continue to transform their practice.

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APPENDIX A

PRISM Learning Community Rubric

Indicators	Beginning	Emerging	Developing	Accomplished
Shared Vision	The facilitator/leader of the learning community has a vision of teaching and learning which includes promoting intellectually challenging work for students and effective teaching practices.	A few of the members of the learning community share a vision of teaching and learning which promotes the development of intellectually challenging work for students and embodies the use of effective teaching practices.	Most of the members of the learning community share a vision of teaching and learning which promotes the development of intellectually challenging work for students and embodies the use of effective teaching practices.	All members of the learning community share a vision of teaching and learning which promotes the development of intellectually challenging work for students and embodies the use of effective teaching practices.
Shared Leadership	The learning community is organized and its work determined by someone perceived to be outside of the community and not directly related to the work.	The learning community is facilitated by one member who is responsible for organizing the meetings and work of the community.	The learning community is co-facilitated by a member from higher education and a member from P-12.	The learning community is facilitated through the input of all P-16 members equally sharing leadership responsibility.
P-16 Faculty Collaboration	The learning community is comprised of only P-12 faculty or	The learning community is either school-based or university-	The learning community is either school-based or university-	The learning community is comprised of P-16 faculty due to the combined

	higher education faculty, thus resulting in no P-16 collaboration.	based. Representatives from the other educational level may be invited to interact with the group from time to time resulting in tentative P-16 collaboration.	based, but includes a representative from the other educational level resulting in a limited P-16 collaboration.	nature of their work, thus resulting in a substantial P-16 collaboration.
Collaborative Inquiry	Educators discuss the effectiveness of classroom practices and teaching materials currently used in their classrooms within their learning community.	Educators study and discuss research-based practices and how they relate to current practice within their learning community.	Educators discuss research-based practices within their learning community and individual members implement a practice in their classrooms based on need or interest. The member implementing decides how the effectiveness of the practice will be measured and reports results to the learning community.	Educators study research-based practices and collaboratively design an action research study that is conducted in their classrooms by the learning community and evidence of student achievement is documented.
Making Results Public	Learning community members share results of collaborative inquiry with their learning community.	Learning community members communicate results of their work with colleagues in their school and district.	Learning community members make presentations of results in regional, state, or national venues.	The results of the learning community work are published and accessible to a wide audience.

APPENDIX B
Focus Group Protocol

Protocol for Focus Group Session

OPENING

SAY: *You participated in the first district Math and Science Partnership (MSP) grant and I'm grateful that you've agreed to participate in this focus group session. In this session, I have some questions about your experiences during the MSP grant and since then. But before we get to the questions, will you tell me* ***what you're currently doing professionally,*** *and* ***how your professional responsibilities have changed,*** *if at all, since the grant.*

DISCUSSION

A. Overall MSP Grant Perceptions

The MSP Grant activities included Lesson Study Sessions, the Best Practices Institute, and College Content Courses.

What, for you, was the most important outcome of this experience?

Can you summarize how or why that happened? Perhaps a story about something that happened to you would help us understand what you mean.

B. Lesson Study

What, for you, was ***memorable*** *about the lesson study project?*

a. *What makes that so?*

Think about **the lesson study components as a whole***: planning the lesson, observing the lesson being taught by a colleague, observing students during the lesson, and reviewing the data afterward.* ***What would you keep or change*** *if you were attempting a professional development experience for your colleagues?*

a. *Why keep that?*

b. *Or, why make that change?*

C. Best Practices Institute

What, for you, is an effective math teacher?

How have your views of **Teaching Math changed** since the institute? Was that because of the institute?

D. Implementation

What changes have you made in your practice *as a consequence of your participation in the MSP grant?*

What barriers have you encountered *in trying to implement ideas from the grant activities?*

E. Colleagues

Many of you participated in the grant activities with a colleague. ***How has that aspect of the grant affected your practice?***

CLOSING

[Ask participant to write individually]:

If you were to write a letter to the grant organizers, what would you say about the grant that you haven't had a chance to say?

Since the MSP grant activities, please list professional development activities that you have participated in.

APPENDIX C

Teacher Interview Protocol

I appreciate you participating in this study. I will be taping the interview to help me stay focused on our conversation and it will ensure I have an accurate record of what we discussed.

Changes

While you were a participant in the MSP grant, sample teaching episodes were collected on video tape. I would like to share a clip from one of those episodes with you.

Reflecting on your classroom teaching video from the MSP grant, what do you notice that is similar about your current teaching? What would you consider to be different from your current teaching?

I would like to ask you some of the questions from The Video Reflection Tool that we used in the original project:

1. Does classroom activity center on mathematical understanding, invention, and sense making by all students?
2. Is the lesson/task mathematically worthwhile for all students?
3. Is the classroom culture such that inquiry, wrong answers, personal challenge, collaboration, and disequilibrium provide opportunities for new learning by all students?

How has your practice as a mathematics teacher changed since this video was taped?

Teacher collaboration

How would you describe collaboration?

On a scale of 1 to 4, with 1 being STRONGLY DISAGREE and 4 STRONGLY AGREE, how would you respond to each statement:

I feel supported by colleagues to try out new ideas in teaching mathematics.

Mathematics teachers in my school have a shared vision of effective mathematics instruction.

Mathematics teachers in my school regularly share ideas and materials related to mathematics.

To what extent do you currently collaborate with other teachers at your school or other schools?

Professional History and TRT Survey

What professional learning or graduate work have you completed since the MSP grant?

Reflecting on your current practice, please respond to the Teacher Reflection Tools Stages Survey from the project. (Attached)

Final Question

Is there anything else you would like to add?

Thank you for your time. If I have any additional questions or need clarification, how and when is it best to contact you?

Note: Additional follow up questions may be added for selected participants based on the Focus Group session.

APPENDIX D
Teacher Reflection Tools Stages Survey (Foreman, 2003)
reprinted with permission

STAGES SURVEY

Imagine a typical day in your mathematics classroom. Study each question on each Teacher Reflection Tool and mark a I, II, III, IV,V, or VI in the chart below to indicate the stage of your practice regarding that question. (For questions that focus on student actions/interactions, identify the stage of your practice as a *facilitator* of such actions/interactions.)

TEACHER REFLECTION TOOLS

Understanding		Culture		Tasks		Content	
Question	Stage	Question	Stage	Question	Stage	Question	Stage
1		1		1		1a	
2		2		2		1b	
3		3		3		1c	
4		4		4		1d	
5		5		5		1e	
6		6		6		2a	
7		7		7a		2b	
8		8		7b		2c	
9		9		7c		3	
				7d		4	
				8			

STAGES OF TEACHING IN TRANSFORMATION

STAGE I
I know nothing or a very little bit about this. It is not an element of my everyday teaching practice.

STAGE II
I can speak about this (e.g., I have heard/read about it), but I don't have a sense for what it really looks, sounds, or feels like. It is not part of my everyday teaching.

STAGE III
I can recognize this when I see or experience it (e.g., in a workshop, on a video, or when visiting another classroom), but I don't normally use it in my teaching. Classroom experimentation has been minimal.

STAGE IV
Although I regularly try to foster/use this in my classroom, student-based data suggests it isn't really "working" yet. There may be fundamental understandings/strategies missing for me. I need to learn more so I can bring about change in student actions and interactions.

STAGE V
I can model this (e.g., when given a lesson or activity as a guide), but it is not an automatic, internal aspect of my thoughts and actions as a teacher. Based on student data, this *frequently* "works" in my classroom, but it's still "slippery" – when challenged by time, unfamiliar content, reluctant students, doubting colleagues, standardized tests, etc., my old beliefs and practices may take over.

STAGE VI
I consistently foster/use this in my classroom, regardless the source of the lesson or activity. It is a regular, natural, internalized element of my teaching.

Regarding the Teacher Reflection Tool question* –________________
____
____
____
______________________________,
based on data about my students' actions and interactions, my current teaching practice is best described as Stage _____.

*For questions that focus on student actions and interactions, assess the stage of your practice as a *facilitator* of those actions and interactions. Base your assessment on informal and formal data about your students' actions and interactions.

TEACHER REFLECTION TOOLS

UNDERSTANDING, INVENTION, SENSEMAKING

Does classroom activity center on mathematical understanding, invention, and sensemaking by all students?

1) Do student explanations emphasize how and why the students' methods do or don't work?
2) Do students determine the correctness/sensibility of an idea or solution based on the mathematical reasoning presented?
3) Do students approach problems and ideas in a variety of ways?
4) Do all students take part in hands-on explorations with models, manipulatives, and other mathematical tools (or is use of such tools limited to teacher or student demonstrations)?
5) Do students use actions, statements, and questions that show genuine interest in others' thinking about mathematics (or do actions/interactions center on getting others to think in certain ways)?
6) Do students listen intently and actively and ask for clarification when they don't understand someone's methods or reasoning?
7) Are student conjectures, generalizations, "what-if" questions, and invented procedures the norm?
8) Is "private think time" honored and encouraged by all?
9) Do students celebrate their mathematical AHA!s and honor the difficulties that may precede such moments?

CLASSROOM CULTURE

Is the classroom culture such that inquiry, wrong answers, personal challenge, collaboration, and disequilibrium provide opportunities for new learning by all students?

1) Do students discuss and debate their mathematical reasoning and justifications about ideas and problems?
2) Do students rely on their own thinking and the mathematical logic and structure of ideas to judge the correctness/usefulness of the ideas (or do they defer to others for authority based on personalities or roles)?
3) Are contradictions a regular source of reflection and discourse?
4) Are "we wonder…" "we think…" and "we predict…" statements about relevant mathematical ideas central to collaborative investigations?
5) Are wrong answers viewed as worthwhile – as sites for learning?
6) Do students willingly report where their thinking is "stuck" and control the level of input regarding how to get "unstuck?"
7) Do students have autonomy in choosing and sharing their methods of solving problems?
8) Do students honor each other's right to solve problems?
9) Are students equitable in their spoken and unspoken messages about all students' mathematical potential?

WORTHWHILE TASKS

Is the lesson/task mathematically worthwhile for all students?

1) Do student actions and interactions focus on invention/understanding of important and relevant mathematics concepts, processes, and relationships?
2) Do student solutions involve complex, nonalgorithmic thinking?
3) Do students search for multiple solution strategies and recognize task constraints that may limit solution possibilities?
4) Do all students reflect intensively and critically on their own and each others' processes and reasoning?
5) Do all students have access and experience challenge and mathematical insight?
6) Do students experience disequilibrium?
7) Does the lesson/task suggest a mathematical vision and purpose beyond the immediate? That is, is there evidence of a meaningful and coherent *mathematical storyline* in development?
   a) Do students draw upon/link underlying math concepts and prior understandings to work through the task?
   b) Do students construct strategies and conceptions that are fundamental to understanding more complex math ideas?
   c) Do students generate and explore conjectures, gener alizations, and *what-if…* and *I wonder…* statements about the mathematics fundamental to the task/lesson and where it is headed?
   d) Do students connect the mathematics ideas to relevant everyday life and/or other mathematics contexts?
8) Do students use a variety of manipulatives and/or other mathematical tools as supports for sensemaking, problem solving, connecting concepts, and inventing strategies and algorithms?

TEACHER CONTENT KNOWLEDGE

Does my knowledge of the mathematics content I teach and my understanding of the trajectory of that content enable me to support important, long-lasting student learning?

1) Do I pose questions and tasks that foster –

a) student generalizations about core mathematical ideas
b) mathematical contradictions and productive disequilibrium?
c) student thinking and discourse about the meanings of underlying mathematical ideas (i.e., beyond explanations of procedures for solving a problem)?
d) student consideration of ideas that are relevant to the mathematical intent of the lesson but that may not otherwise surface?
e) access, engagement, and challenge for all students?

2) Do I listen intently to my students' thinking and respond according to its mathematical implications, i.e., according to –

a) the alignment of students' thinking with research-based information on the development of students' mathematical thinking?
b) the mathematical validity of students' thinking?
c) the mathematical direction in which we are headed?

3) Do I ground my decisions about whether/how to pursue a student-generated question or idea according to its potential to be mathematically fruitful and its relevance to our mathematical agenda?

4) Do I openly learn and grow with my students?

APPENDIX E

MSP Project Survey, June 2007

Summary of Likert Scale questions on Teacher Survey (n=27)
Scale: 1=Strongly Agree, 2=Agree, 3=Neutral, 4=Disagree, 5=Strongly Disagree

Question	Mean	Mode
1) My involvement and participation in the MSP helped me improve my content knowledge.	1.89	2
2) My involvement and participation in the MSP helped me learn new ways to teach.	1.70	1
3) Collegial classroom observations (peers observing my class or me observing others' classes) increased as a result of my involvement and participation in the MSP.	2.26	2
4) The use of video reflection (VAT) has been (would be) a worthwhile aspect in my classroom practices?	2.11	2
5) The use of video reflection (VAT) has helped (would help) my strategic planning for teaching.	2.19	2
6) I have increased the amount of collaborative planning and lesson discussion I have with my peers as a result of my involvement and participation in the MSP.	1.78	1
7) My participation in the MSP has made it easier for me to effectively assess my students in multiple ways.	1.70	1
8) My students' achievement has improved as a result of my involvement with the MSP.	2.07	2
9) My effectiveness as a teacher has improved as a result of my involvement in the MSP.	1.67	2
10) Collaboration with teachers from other schools has positively changed the way I teach.	1.93	2
11) I plan to continue collaborating with teachers from other schools after the MSP.	1.81	1
12) I plan to continue collaborating with teachers from my own school after the MSP.	1.52	1

MSP Project Survey Responses

Name	**Q1: Please list the MSP activity (activities) in which you were a participant.**	**Q2: Has your involvement and participation in the MSP impacted your overall classroom practices? Explain/describe.**	**Q3: Has your involvement and participation in the MSP affected the way you assess your students? Please describe.**	**Q4: Has your involvement in the MSP affected the way you teach? If so, in what ways?**	**Q5: What, to you, was/were the most useful activity(ies) in the Math and Science Partnership? Why?**	**Q6: What, to you, was/were the least useful activity(ies) in the Math and Science Partnership? Why?**
Alicia	Best Practices, Groupwork, Lesson Study, TI-workshop, Jason, GPS, VAT	Yes. I am more critical of how my actions impact student learning.	No. I feel like I still use most of the same tools for assessment.	Yes. Things that I used to do just out of tradition, I no longer do	VAT, GPS, Best Practices and TI. They really allowed me to do some self-assessment as to the efficacy of my teaching style.	Jason. The content was very good, but I never had time to put the activities together and incorporate them into my curriculum.
Daniel	All of them!!! Videotaping, Lesson Study, Best Practices, all of the staff develoment that coincided with this grant!	YES! All resources were extremely helpful. The instructional practices and protocols empowered my students to express their knowledge.	It has reaffirmed my multiple ways of assessment.	My style is more in-depth because of some of the protocols from the Best Practices.	The Best Practices protocols allowed more insight to "why" and "how" than previously.	GPS 8th grade training. I wanted more! I needed more!
Jessica	videotaping, videotape analysis online, Jason, Best Practices, Groupwork	I have been able to incorporate more science content into my math classroom and work with the science teacher on my team. I have done LOTS more group work and feel more confident in designing and evaluating good group work. I feel like I do lots more reflection on my practices of instruction than I used to.	I do more rubrics, more formative assessment in a "formal" way, and I rely less on the traditional tests (I can't remember the last time I used a "book test"!)	Yes, I do more small group, partner, and split group teaching and lots less whole group instruction and note-taking.	I think the groupwork staff development class was definitely the most useful because it has made the largest impact in my daily teaching. Best Practices workshop would be #2.	I didn't use Jason training very much because my science teachers on my team wasn't very into it so I had trouble keeping up the momentum.

Susan	Summer courses, i.e. Best Practices, Teamwork/Groupwork, VAT, Jason, GPS, Lesson Study	Yes, I used several techniques and strategies to teach pre-algebra and algebra. MSP allowed me to assess my style of teaching.	Yes! Just as I learned differently from my co-workers/team-mates in the workshops, my students learn differently.	MSP Has affected the way I teach. The Groupwork session proved the importance of it in ways I wasn't aware of.	Best Practices and Groupwork were most useful because they both caused me to think "outside" the box.	All were useful but if I had to choose one it would be Jason only because some topics were another subject.
Valeria	Math and Science, Jason, GPS, Summer Inst., Best Practices, Lesson Study, Mathematics GPS training, Groupwork, TI-workshop, VAT	Yes. I've exposed my students to different ways of learning and thinking about math. I've changed my teaching strategies to better involve my students into talking and learning math.	Yes--I learned that there are many ways to assess (not just paper and pencil)	Yes--there have been changes in my assessing students (proving questions and discussion, groupwork assessment, student directed learning, etc.)	Best Practices and designing groupwork because these activities probed into student thinking about math and provided an array of assessing students.	They were all beneficial and useful in some way.

APPENDIX F
District Instructional Practices Survey

District Instructional Practices Survey – September 2008

Middle School Math Survey

This survey is part of a comprehensive effort to evaluate the next steps in our district mathematics improvement plan. Thank you for taking time to participate!

1: Students generally learn mathematics best in classes with students of similar abilities.

- Agree
- Strongly Agree
- Disagree
- No Opinion
- Strongly Disagree

2: I feel supported by colleagues to try out new ideas in teaching mathematics.

- Agree
- Strongly Agree
- Disagree
- No Opinion
- Strongly Disagree

3: Mathematics teachers in my school have a shared vision of effective mathematics instruction.

- Agree
- Strongly Agree
- Disagree
- No Opinion
- Strongly Disagree

4: Mathematics teachers in my school regularly share ideas and materials related to mathematics.

- Agree
- Strongly Agree
- Disagree
- No Opinion
- Strongly Disagree

5: Mathematics teachers in my school are well-supplied with materials for investigative mathematics.

- Agree
- Strongly Agree
- Disagree
- No Opinion
- Strongly Disagree

6: I have time during the regular school week to work with my peers on mathematics curriculum and instruction.

- Agree
- Strongly Agree
- Disagree
- No Opinion
- Strongly Disagree

7: I have adequate access to calculators for teaching mathematics.

- Agree
- Strongly Agree
- Disagree
- No Opinion
- Strongly Disagree

8: I have adequate access to computers for teaching mathematics.

- Agree
- Strongly Agree
- Disagree
- No Opinion

- Strongly Disagree

9: I enjoy teaching mathematics.

- Agree
- Strongly Agree
- Disagree
- No Opinion
- Strongly Disagree

10: I am well-informed about the Georgia Performance Standards (GPS).

- Agree
- Strongly Agree
- Disagree
- No Opinion
- Strongly Disagree

11: How prepared do you feel to provide concrete experiences such as manipulative use for your students before moving to abstract concepts?

- Very Well Prepared
- Fairly Well Prepared
- Somewhat Prepared
- Not Adequately Prepared

12: How prepared do you feel to develop students' conceptual understanding of mathematics?

- Very Well Prepared
- Fairly Well Prepared
- Somewhat Prepared
- Not Adequately Prepared

13: How prepared do you feel to take students' prior understanding into account when planning curriculum and instruction?

- Very Well Prepared
- Fairly Well Prepared
- Somewhat Prepared
- Not Adequately Prepared

14: How prepared do you feel to make connections between mathematics and other disciplines?

- Very Well Prepared
- Fairly Well Prepared
- Somewhat Prepared
- Not Adequately Prepared

15: How prepared do you feel to have students work in cooperative learning groups?

- Very Well Prepared
- Fairly Well Prepared
- Somewhat Prepared
- Not Adequately Prepared

16: How prepared do you feel to have students participate in hands-on activities?

- Very Well Prepared
- Fairly Well Prepared
- Somewhat Prepared
- Not Adequately Prepared

17: How prepared do you feel to have student use graphing calculators?

- Very Well Prepared
- Fairly Well Prepared
- Somewhat Prepared
- Not Adequately Prepared

18: How prepared do you feel to have students use Geometer's Sketchpad software?

- Very Well Prepared
- Fairly Well Prepared
- Somewhat Prepared
- Not Adequately Prepared

19: How prepared do you feel to use performance-based assessments such as GPS tasks?

- Very Well Prepared
- Fairly Well Prepared
- Somewhat Prepared
- Not Adequately Prepared

20: How prepared do you feel to use portfolios?

- Very Well Prepared
- Fairly Well Prepared
- Somewhat Prepared
- Not Adequately Prepared

21: Many teachers feel better prepared to teach some mathematics topics than others. How well prepared do you feel to teach ALGEBRA?

- Not Adequately Prepared
- Somewhat Prepared
- Fairly Well Prepared
- Very Well Prepared

22: How well prepared do you feel to teach GEOMETRY?

- Not Adequately Prepared
- Somewhat Prepared
- Fairly Well Prepared
- Very Well Prepared

23: How well prepared do you feel to teach STATISTICS (e.g. hypothesis testing, curve fitting and regression)?

- Not Adequately Prepared
- Somewhat Prepared
- Fairly Well Prepared
- Very Well Prepared

24: How well prepared do you feel to teach PROBABILITY?

- Not Adequately Prepared
- Somewhat Prepared
- Fairly Well Prepared
- Very Well Prepared

25: How well prepared do you feel to teach topics from DISCRETE MATHEMATICS (e.g. combinatorics, graph theory, recursion)?

- Not Adequately Prepared
- Somewhat Prepared
- Fairly Well Prepared

Very Well Prepared

26: How well prepared do you feel to teach FUNCTIONS (including trigonometric functions) and PRE-CALCULUS topics?

- Not Adequately Prepared
- Somewhat Prepared
- Fairly Well Prepared
- Very Well Prepared

27: How well prepared do you feel to teach CALCULUS?

- Not Adequately Prepared
- Somewhat Prepared
- Fairly Well Prepared
- Very Well Prepared

28: Reflecting on your own practice, what are your goals for mathematics professional learning this year?

APPENDIX G
Mathematics Tasks Framework
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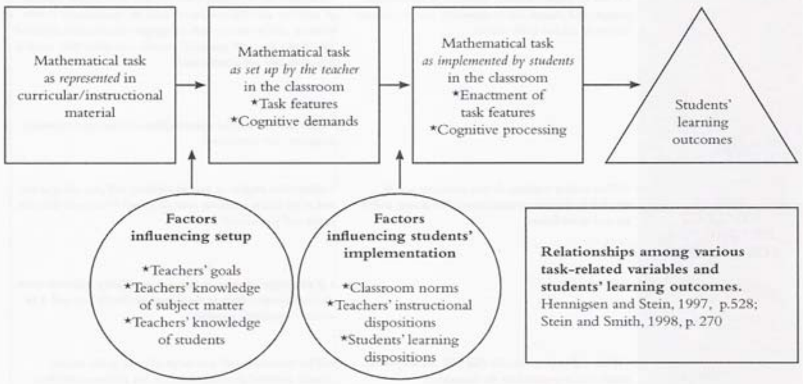
MATHEMATICS TASKS FRAMEWORK



Relationships among various task-related variables and students' learning outcomes. Hennigsen and Stein, 1997, p.528; Stein and Smith, 1998, p. 270

This framework was used to analyze hundreds of lessons between 1990 and 1995. This research has yielded two major findings:

1) Mathematical tasks with high-level cognitive demands were the most difficult to implement well, frequently being transformed into less-demanding tasks during instruction.

2) Student learning gains were greatest in classrooms in which instructional tasks consistently encouraged high-level student thinking and reasoning and least in classrooms in which instructional tasks were consistently procedural in nature.

(Stein, Smith, Hennigson, and Silver, 2000)