The Impact Of A Math Mentoring Program To Prepare New Elementary Teachers To Teach Mathematics

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ABSTRACT
THE IMPACT OF A MATH MENTORING PROGRAM
To PREPARE NEW ELEMENTARY TEACHERS TO TEACH MATHEMATICS
by
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This qualitative case study examined the effect the first year of an elementary mathematics induction program had on the mathematics content knowledge and pedagogy, confidence, classroom practice, and student achievement for six new elementary teachers in a suburban school district. The study also examined which components of this job-embedded professional development program influenced the teachers’ practice the most.

Data was collected from the six volunteer teachers through semi-structured interviews, questionnaires, journals, and student assessment results. The major findings from the study showed that: (1) teachers’ perception of their instructional practice, particularly their ability to question student thinking, math content knowledge, and confidence to teach mathematics improved as a result of the program; and, (2) teachers benefited the most from the opportunity to regularly observe their mentor teach a mathematics lesson, followed by the opportunity to discuss mathematics and related pedagogical issues with their cohort and mentor.

Implications from the findings include the benefit of instituting content-focused, job-embedded professional development during a new teacher’s first year in a district that
provides regular opportunities for new teachers to observe a skilled veteran teacher teach a mathematics lesson and to have peer discussions regarding the teaching of mathematics.

Limitations of the study included the role of the Assistant Superintendent as researcher and developer of the program and the small sample size. Recommendations for future study include the following: the effect on teaching practice after the second year in the math mentoring program; the effect of the program on mentors; the effect of mathematics self-efficacy on mathematics teaching self-efficacy and student achievement.
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DEDICATION

- And finally, to my husband, Paul Kelly, whose love, support, kindness, and humor has sustained me through our life together. It is with gratitude and deep love that I dedicate this dissertation to him.
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Chapter I
Overview of the Study

I. Introduction

Since the publication of *A Nation At Risk* (National Commission on Education, 1983), a “seeming endless stream of studies, commissions, and national reports have targeted teacher quality as one the central problems facing schools” (Ingersoll, 2004, p.1).

The quest to improve teacher quality in the United States has spawned legislation at both the state and federal levels to improve the preparation and quality of teachers, as well as, create the means to hold schools accountable for the academic achievement of students.

Due to the mandates of the federal *No Child Left Behind* Act of 2001 (NCLB), all students are expected to attain math and literacy proficiency by 2014. Public schools must show Adequate Yearly Progress (AYP) toward that goal. Teachers, veteran and new, feel the pressure to have their students perform well on state assessments, which are the basis for demonstrating progress. The expectation for student achievement is the same for new teachers as it is for veteran teachers. Given the pressures schools and school districts are under to have students continuously improve their performance in mathematics, it is imperative that new teachers be able to competently teach mathematics.

In response to the standards based movement shaped by the 1993 Massachusetts Education Reform Act and amplified by NCLB, Massachusetts tests students annually in mathematics and literacy in grades 3-8 and in grade 10. In order to receive a high school diploma students must pass the Grade 10 MCAS exam. Progress for districts is measured
for the aggregate as well as subgroups (special education, free and reduced lunch, and minority groups).

Public schools must show Adequate Yearly Progress (AYP) toward the 2014 proficiency goal for the aggregate, as well as, for each identified subgroup of students, even though it is not the same group of students being tested at a given grade level each year.

The consequences of ‘not making AYP’ are both political and financial. Community desirability and prestige are linked to district rankings on MCAS. If a school has multiple years of not meeting AYP, the school runs the risk of being put into receivership by the Massachusetts Department of Education. While for most suburban schools this is not a serious risk, ‘not making AYP’ creates morale issues in individual schools and engenders central office pressure to show improvement on future assessments. For suburban schools, generally the biggest issue is “not making AYP” for subgroups rather than the aggregate.

School districts which are designated as Title 1 districts or have schools which qualify for Title 1 funds face added burdens by not making AYP. After two years of not making AYP in the aggregate or in a subgroup, parents of children in Title 1 schools must be offered the opportunity to transfer to another district school which has made AYP across all groups. Districts can also incur transportation costs for transferred students. Additionally, schools must create an education plan for students who have failed or are in the warning category on MCAS. Title 1 schools must allocate sufficient funding to help remediate the deficiencies identified by MCAS for these students.
Only a few years ago, the effect of lower proficiency scores among the students in a new teacher’s class could be “absorbed” in the school or district aggregate when there were more veteran teachers than new teachers. As the ratio of new teachers to veteran increases, it has become important that students of all teachers regardless of experience and education background perform well.

The quest to improve teacher quality in the United States has spawned legislation at both the state and federal levels to improve the preparation and quality of teachers. The NCLB law mandates that highly qualified teachers be in every public school classroom by the 2005-2006 school year. The law defined “highly qualified” teachers as persons with subject matter mastery. However, the competencies which demonstrate subject matter mastery can vary among states. Most states have adopted teacher testing as a means to ensure that only highly qualified teachers (as state defined) obtain licensure (National Conference of State Legislatures, 2005).

In Massachusetts, a prospective teacher must have a BA or BS degree and pass both a subject competency (for elementary teachers this is a general curriculum test) and a literacy test in order to receive a preliminary teaching license.

To be eligible for licensure as a Preliminary or initial educator . . . . The candidate shall pass a test established by the board which shall consist of two parts: (A) a reading and writing section which shall demonstrate the communication and literacy skills necessary for effective instruction and improved communication between school and parents; and (B) the subject matter knowledge for the license. [M.G.L. c. 71 s. 38G]
The general curriculum test for elementary teachers in Massachusetts consists of 100 questions (www.doe.mass.edu). Twenty-two of the questions relate to math. While the percentage of math questions may reflect the relative proportion of time devoted to teaching mathematics each day in many schools, it does not reflect the weight the state places upon student achievement in mathematics as measured by MCAS. Given that only 22% of the competency test questions measure mathematics knowledge, it is possible for elementary teachers to fail the mathematics portion of the test and still pass the general curriculum test.

State certification requirements and university teacher preparation programs are responding to the need that elementary teachers have more extensive preparation to teach mathematics. Beginning in 2008, prospective elementary teachers in Massachusetts will be required to pass a separate test in mathematics. Many college and university teachers’ post-BA/BS preparation programs have made or are considering making successful results on the state certification tests a mandatory requirement for admission.

Veteran teachers must also maintain their “highly qualified” status by continuing to take courses or other professional development activities that award professional development points for recertification, which is required every five years.

Complicating the ability of school districts to meet the goals of NCLB is the shortage of teachers who have a strong knowledge base in mathematics. Moreover, it has become increasingly difficult, in general, to retain teachers for more than a few years. Nationwide, it is estimated that nearly forty to fifty percent of new teachers leave the classroom within five years (Ingersoll & Kralik, 2004). In Massachusetts, the attrition
rate of new teachers in urban areas equals or exceeds the highest national rate. Cities in Massachusetts lose fifty percent of new teachers in their first three years of teaching (Brady-Myerov, 2007), while the rate in the suburbs is thirty percent (Conti, 2004, p. 3). These rates have remained fairly consistent over the last few years, costing districts precious financial resources and compromising the achievement of students.

In Massachusetts, these retention rates are quite troubling in light of the growing number of teachers who are retiring. In the next five years, 21,400 teachers will retire, which is a nineteen percent increase over the previous five years. Nearly half of the teachers in Massachusetts are from the baby-boom generation (Brady-Myerov, 2007).

Cities and towns have increasingly been forced to apply for waivers in certain fields, such as, mathematics, chemistry, and special education, to allow non-certified teachers to fill the void. Some educational forecasters have described the current situation of increasing retirements coupled with the high attrition rates of new teachers as the perfect storm in education (Brady-Myerov, 2007, Conti, 2004).

Research has shown that there is a positive effect on achievement for students who are taught by a teacher with more than three years teaching experience (Murnane & Phillips, 1981). The challenge to meet the proficiency goals of NCLB is considerable if experienced teachers are the minority in every school. In the suburban district of this study, nearly two-thirds of the elementary teachers were new to the district in the previous four years.

There is considerable research on the variables which contribute to teacher dropout, as well as, the influences which support teacher retention. Numerous studies
(Kardos & Johnson, 2007; Little, 1990a; Murnane & Phillips, 1981) document the difficulties new teachers encounter in the first years of their careers. Ingersoll (2001) found that teachers left the profession because of salaries, lack of administrative support, discipline issues, student motivation, and a lack of voice in decision-making. Strong (2005), reporting on the findings of several studies, indicates that stress is another powerful factor that motivates teacher attrition. Stress can result from working conditions, lack of self-efficacy and satisfaction, or lack of positive feedback from colleagues and principals.

Kardos and Johnson (2007) in their study of 486 first-year and second-year full-time, K-12 public school teachers from four states also found that the organizational structures of schools contributed to teacher retention, including their experience of the professional culture. They defined ‘professional culture’ as the “established modes of professional practice among teachers; their norms of behavior and interaction; and the prevailing institutional and individual values that determine what teachers do and how they do it” (p. 2). Professional cultures are influenced by “mentoring, classroom observations, teacher meetings, collaboration, and professional development” (p. 2).

Kardos and Johnson’s (2007) survey responses reveal that many of the new teachers felt that they are expected to be independent and expert from the start. Nearly half the new teachers (49%) in the sample reported that they plan lessons alone and teach alone. “This is bad news given that, for most, teaching is too complicated an art and craft to be mastered in isolation. The frustrations associated with new teachers’ early career failures are partially responsible for their turnover, whether they transfer to another
school or leave teaching altogether” (p. 9). In their study, 67% of Massachusetts teachers report that they teach and plan alone, “despite the fact they are trying to learn how to do their job within the challenging context of standards-based reform and high-stakes, statewide testing” (p. 9).

II. Focus of the Study

In response to these concerns of teacher preparation and retention, a Massachusetts suburban school district developed a two-year elementary mathematics induction program (Math Mentor Program) to prepare new and new-to-their-grade teachers to teach the mathematics curriculum. The components of the first year of the Math Mentor Program include lesson modeling by the mentor, mentor-led discussions and sharing of best practices with the new teacher cohort, and mentee journal reflections. The program is embedded into the school day to ensure that all new teachers participate. The school-time given to the training communicates to the teachers the importance the district places on excellent mathematics instruction. The structure of the program fosters collaboration among new teachers and mentor teachers.

The elementary mathematics program used in the district is TERC’s *Investigations into Number. Space and Data*, which is a standards-based, constructivist program. The program requires that teachers have a strong and versatile knowledge of mathematics in order to engage students in dialogue about mathematics. The curriculum is designed to:
• Support students to make sense of mathematics and learn that they can be mathematical thinkers.

• Focus on computational fluency with whole numbers as a major goal of the elementary grades.

• Provide substantive work in important areas of mathematics—rational numbers, geometry, measurement, data, and early algebra—and connections among them.

• Emphasize reasoning about mathematical ideas.

• Communicate mathematics content and pedagogy to teachers.

• Engage the range of learners in understanding mathematics.

(http://investigations.terc.edu/)

Constructivist mathematics programs involve students in the investigation of mathematical concepts and problems. A constructivist approach emphasizes student understanding and explaining rather than memorizing and “doing” what is modeled by the teacher.

A mathematics standards-based program has clearly defined goals that align with the mathematics benchmarks defined by NCTM and state curriculum framework documents. The teacher should know what the mathematics goals are and structure her instruction to achieve those goals. Success is measured by student achievement on state and district assessments. The standards reflect what we believe students should know and be able to do in mathematics at different stages of development.
Math Mentor Program Design – Year 1:

Teachers in the first year of the Math Mentor Program meet with their grade-level math mentor in August for one day prior to the start of the school year to review the goals of the mathematics curriculum, the common assessments (6-8 assessments for each grade), the curriculum pacing chart, and to plan September’s lessons. They meet six additional times during the year for two and half hours in the mentor’s classroom to observe the mentor teach an Investigation Into Number, Data and Space lesson and to discuss the lesson and any other difficulties the teachers are experiencing with the curriculum.

This case study was designed to research the effectiveness of the first year of the Math Mentoring Program for training new teachers in grades K-5 to teach mathematics using TERC's Investigations Into Number, Data and Space as the central curriculum.

III. Research Questions

1. How did the Math Mentoring Program affect participating teachers’ perceptions of their ability to teach the mathematics curriculum, Investigations Into Number, Data and Space?
   a) What math content did they learn?
   b) What math pedagogy did they learn?
   c) What effect did the program have on their confidence to teach mathematics?
   d) How was student achievement affected?
e) What classroom practices were instituted or changed as a result of their participation?

2. How did the various components of the Math Mentoring Program contribute to new teachers’ perceptions of their improved content knowledge, pedagogical strategies, confidence, and classroom practices?
   a) What was the effect of observing a mathematics lesson taught by the mentor?
   b) What was the effect of group discussions with the cohort group and mentor?
   c) What was the effect of keeping a reflective journal?
   d) What was the effect of reading articles focused on math pedagogy?

IV. Theoretical Rationale

There is urgency in the United States to improve the mathematics education of its children. There are large gaps in achievement between the United States and other countries (TIMSS, 2003) and among states. The global economy is increasingly dependent upon a workforce that has strong numeracy and problem-solving skills. Federal legislation (No Child Left Behind Act of 2001) requires that all students be proficient in mathematics by 2014.

Recent research shows that a teachers’ mathematical knowledge has a positive effect on student achievement, accounting for 12-14% of the variability of student performance on achievement tests (Ball, 2008). Marzano (2003) in summarizing the research of the last thirty years regarding what factors makes the biggest difference in
student achievement found that that teacher-factor had the most influence and the effect can be cumulative over years. In a study of elementary students in Tennessee, Marzano (2003) reports “a 54-percentile point discrepancy in achievement gains between students with least effective teachers – 29 percentage points respectively over three years versus 83 percentage points respectively over three years” (p. 73).

Darling-Hammond (2000) found that “while student demographic characteristics are strongly related to student outcomes at the state level, they are less influential in predicting achievement levels than variables assessing the quality of the teaching force…teacher quality variables appear to be more strongly related to student achievement than class sizes, overall spending levels, teacher salary levels…or such factors as the statewide proportion of staff who are teachers” (p. 38). Darling-Hammond (2000) also found that students did better on standardized tests when teachers had both pedagogical and course work training in their subject area.

Starratt addressed the issue of teacher preparation from a social justice perspective. In an era of accountability, students must be given equal opportunities to learn. Given the research regarding the effect of teachers’ content knowledge on performance, this implies that school districts have the responsibility to hire and train teachers who will provide students with an equal opportunity to learn. “The logic of test-based accountability says that schools have to be relentlessly inventive in finding ways to help students learn…Furthermore, schools that tolerate ineffective instruction and inadequate curriculum materials or ignore obstacles to learning will no longer be accepted” (Starratt, 2003, p. 300). Darling-Hammond and Sykes (2003) write, “As the
importance of well-qualified teachers for student achievement has become increasingly clear, this source of inequality has become more and more difficult to justify or ignore” (p. 3).

In addition to content knowledge and pedagogical training, research (Hoy & Spero, 2005; Bandura, 1997; Armour et al., 1976) has shown that teachers’ sense of efficacy is another major predictor of teacher effectiveness. Teacher’s sense of efficacy is defined as “teachers’ judgments about their ability to promote student learning” (Hoy & Spero, 2005, p343). Teacher efficacy was identified thirty years ago in a study by the RAND corporation as “one of the few teacher characteristics related to student achievement (Armor et al., 1976).

Bandura (1977) proposed a theory of self-efficacy, which is developed through four types of experiences, the most powerful being mastery experiences. One type of mastery experience relates success to knowing a subject thoroughly (subject content knowledge).

A second source for efficacy expectations is vicarious experiences. “Vicarious experiences are those in which someone else models a skill. The more closely the observer identifies with the model, the stronger will be the impact on efficacy” (Hoy & Spero, 2005). Observing a mentor teacher teach a lesson is an example of a vicarious experience.

The research work of Bandura and others suggest that a teacher’s sense of efficacy can be affected more in her earlier years of teaching than later. Bandura (1997) found that the level of support a teacher had in her first year of teaching correlated
positively with self-efficacy (Hoy & Spero, 2005), which by itself indicates the importance of induction programs that provide significant support for new teachers.

A barrier for some elementary teachers in developing self-efficacy for teaching mathematics is their anxiety about mathematics. Mathematics anxiety has been defined as “a state of discomfort, which occurs in response to situations involving mathematical tasks, which are perceived as threatening to self esteem” (Trujillo & Hadfield, 1999, p.1). Trujillo and Hadfield (1999), as a result of their study of 50 pre-service teachers, felt that “the most practical solution (to minimizing mathematics anxiety) is to provide elementary mathematics methods courses and professional development opportunities that reduce mathematics anxiety through the development and delivery of cutting edge lessons in mathematics for elementary school children” (p.10).

As mentioned earlier, public schools in the United States are experiencing serious teacher retention problems, as well as, the possibility of a teacher shortage in the next five years (The Boston Globe, 2007). “Nearly forty percent of teachers leave the profession within their first five years of teaching” (Ingersoll, 2001). The potential shortage is due to the combined factors of teachers who are retiring and those who are leaving the profession after only a few years.

Johnson (2006) writes:

From the perspective of the school, the departure of an experienced, effective teacher reduces the school’s capacity to do its work. When a departing teacher leaves…that individual takes away an acquired expertise and accumulated
knowledge about the students, their families, the curriculum, and the school’s practices. Such turnover severely compromises the chance that all students will be taught by effective teachers (p.3).

The National Commission on Teaching and America’s Future (2003) emphasizes the importance of retention, “The ability to create and maintain a quality teaching and learning environment in a school is limited not by teacher supply, but by the high turnover among the teachers who are already there” (p.8).

Research shows that attrition rates improve when new teachers are provided with a comprehensive induction program, as distinguished from a mentoring program in which the new teacher is assigned a veteran teacher to help her adjust to the new school culture (Ingersoll, 2001). Strong (2005) in his study of 72 teachers who had been given a comprehensive induction program found that 88% of these teachers were still teaching six years later, though not necessarily in the school or district in which they had been trained.

Comprehensive induction programs include most, if not all, of the following characteristics:

- School and district orientation programs
- Mentoring relationships, which include observations, co-teaching, and joint lesson planning.
- Individualized plans for growth and development.
• Support teams with veteran teachers including regular opportunities to observe and be observed by other teachers.

• Workshops and training for both new teachers and mentors

• Formal evaluation by a supervisor to gain an understanding of strengths and weaknesses.

• Modified teaching schedule or assignments in which teachers receive smaller loads, fewer preps, or less difficult classes.

• Opportunities to participate in professional learning communities.

(www.doe.mass.edu; www.nwrel.org)

While there is fairly strong evidence from a number of research studies (Ingersoll, 2004; Johnson & Kardos, 2002; Mitchell & Scott, 1999; Kelley, 2004) that comprehensive induction programs have a positive effect on teacher retention, little research, except for the current Department of Education study (to be released in 2008), has been done to study the effects of new teacher induction programs on student achievement during a teacher’s first years of teaching. We do know from Bandura’s work (1997) that there is a positive correlation between perceived support and self-efficacy, which is a predictor of whether a teacher stays in the profession.

Darling-Hammond (1999) concluded in her study of state policies on teacher quality and student achievement that “states interested in improving student achievement may be well-advised to attend, at least in part, to the preparation and qualifications of the teachers they hire and retain in the profession” (pp. 38-39).
Given the often limited preparation most new elementary teachers have for teaching mathematics, an induction program should provide opportunities to improve new teachers’ mathematics content knowledge and pedagogical skills, thereby, helping them to effectively nurture the mathematical proficiency of their students. “Mathematical proficiency refers to the goals of successful mathematics instruction reflected in these five interdependent strands: conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, and productive disposition (NRC, 2001).

Timmerman (2004) in her study of interventions that impact prospective elementary teachers’ beliefs about teaching mathematics concludes that:

When mathematics teacher educators provide prospective teachers with opportunities to learn how to contribute to and implement the strands of mathematical proficiency, prospective teachers are obligated to confront their existing beliefs, knowledge, and abilities about what it means to know and do mathematics, how children learn mathematics, and strategies for teaching mathematics (p. 369).

This statement suggests that when the focus of mathematics induction programs is the development of teachers’ pedagogical skills, an extended benefit is that teachers’ knowledge of mathematics will also deepen through the experience, as well as, their understanding of how children learn mathematics.
Ball and Cohen (1999) describe these principles of professional development as “learning in practice”, which “at the core is about learning professional performance...Professional learning must be centered in the central activities of the profession, that is, in and about the practices of teaching and learning” (p. 13). Reflection and discourse about practice are also key elements of an effective professional development program. Ball and Cohen (1999) also acknowledge the importance of cultivating content knowledge and skills through the professional learning activities.

Feiman-Nemser (2001) concurs that:

New teachers need a compelling vision of good teaching and a beginning repertoire of approaches to curriculum, instruction, and assessment consistent with the vision. A major task of induction is helping new teachers enact these approaches purposefully with their students by developing the necessary understanding and flexibility of response (p1029).

Neo-Piagetian theory and research (English, 1999), which is based on Piaget’s work, provides promising guidelines to help educators plan learning opportunities for adult learners. The why of what new teachers need to know is fairly clear in the context of the expectations and standards of student learning and achievement for which they are held accountable.

The implications of the work of Knight and Sutton (2004) when applied to professional development for new teachers is that it is a more transforming experience to
provide opportunities to learn pedagogical skills in a classroom setting than in a workshop or unrelated setting. Concepts and skills learned through classroom observations and practice are more robust and longer lasting than those learned in non-related contextual settings.

Oji (1980) who studied adult learners as related to teacher in-service education identified four important characteristics for successful adult learning:

- Concrete experiences that are transferable to their teaching.
- Available resources for supervision and advising.
- Encouragement and opportunities to assume new and complex roles.
- Support and feedback when implementing new programs and strategies.

Veteran educators who assume mentoring roles in the induction of new teachers grow in their pedagogical skills as well. Little research has focused on the professional growth of mentor teachers. To the extent that mentor teachers expand their own repertoire of skills through the mentoring experience should influence positively their cognitive developmental, which, in turn, correlates with improved student achievement.

Another benefit to a school and/or district that supports mentorship/induction programs is leadership capacity building. Central to most school improvement plans is the development of professional learning communities. “The term ‘professional learning community’ is one that implies a commitment not only to teacher sharing but also the generation of a school-wide culture that makes collaboration expected” (Harris, 2003, p. 321). Much is known about the benefit of professional learning communities on teacher development, thus, student achievement. The issue is how these learning communities
develop and flourish. In professional learning communities “teachers participate in decision-making, have a shared sense of purpose, engage in collaborative work and accept joint responsibility for the outcomes of their work” (Harris, 2003, p.321). Frost and Durrant (2003) note, “It is not a matter of delegation, direction or distribution of responsibility but rather a matter of teacher agency and their choice in initiating and sustaining change”(p. 174), which is why building teacher leadership capacity is essential to the sustainability of professional learning communities.

The urgency for the United States to improve mathematics education is not easily addressed without considering the content knowledge needed for teaching mathematics, providing teachers with the pedagogical knowledge and skills needed for teaching, and developing programs to improve teacher retention.

V. Significance of the Study

The significance of this project goes beyond the perimeters of the district. Most, if not all, school districts are struggling with the same challenge of how to improve the mathematics content knowledge and pedagogical skills of their elementary teachers, many of who are inadequately prepared to teach mathematics. Given the influence that the new NCTM focal points and the National Mathematics Advisory Panel Report (2008) will have on mathematics education (more depth and less breadth); it is going to be increasingly more important that elementary teachers have a strong mathematics background. The Massachusetts Department of Education has recognized this need by increasing the math requirements for elementary certification beginning in 2008. While
this is an important policy change, it does not address the mathematics education needs of already hired teachers. The focus of this study will help answer the question: Does the Math Mentor Program offer other districts an effective professional development model to improve the content knowledge, mathematical pedagogy, and confidence of new elementary teachers to teach mathematics?

VI. Research Design

This research project was designed to be an evaluative descriptive case study that researched the effect of the first year of a Math Mentor Program on teachers’ perceived gains in content knowledge, instructional pedagogy, and confidence. The group of new teachers included those who were new to the district or new to their grade-level. This case study sought to extend the knowledge base of what characterizes an effective content-based induction program for new teachers.

The methodological component of the research study included a variety of protocols, including teacher interviews, observations of mentor meetings, questionnaires, and reflective journals. Data was collected with consideration for reliability, validity, and evidence of researcher bias. The researcher of the project designed the Math Mentor Program, selected the mentor teachers, and developed the protocol instruments (with input from mentor teachers and expert collaborators). To minimize the effect of researcher bias, data displays were subjected to the scrutiny of an objective expert group, who were not be participants in the program.
Interviews were conducted with a small sample of six teachers who participated in the Math Mentor Program. The sample group of teachers represented different grade levels. The questions asked in the interviews were based on the research questions. The teacher interview questions were reviewed with a small group of mentor teachers and an expert group made up of principals and teachers from outside the district.

All interviews were fully transcribed from audiotapes. Responses were coded using the same categories that were used to code the questionnaires, journals, and observations. Pattern counts were used to track the frequency of responses in order to report trends and emphasis. During the interview, the researcher asked clarifying questions.

Survey questions evolved over the unfolding of the project to better reflect the study goals of the project. Survey questionnaires were given to teachers both at the beginning and end of the school year. Responses to the beginning of the year (initial) survey questionnaire were coded the same way as responses to the end-of-year survey.

In the year of the study, all teachers were asked to keep a reflective journal in which they responded to guiding questions about an observation in the time frame between mentor sessions. Their journals were turned into the researcher at the end of the school year. The researcher, however, read installments of their journals during the school year to follow their progress in the program. Journals were coded in the same manner as interviews, questionnaires, and observations.
VII. Limitations of the Study

Due to the fact that the researcher is the same person who designed the Math Mentor Program, selected the mentors, and designed most of the data gathering instruments, there may be some bias in the analysis of the results that align positively with the researcher’s hopes and expectations for the success of the program.

Another potential bias is that teachers may have agreed to be a participant in the study because they thought that their participation would please the researcher who is the Assistant Superintendent.

The previous teaching or educational experiences of the new teachers could have been a significant factor in a teacher’s gain in mathematics content knowledge and pedagogical competency. Since most learning is an associative process, teachers’ educational and/or experiential background most likely influenced what they learned through participation in the Math Mentor Program. Teachers with less of a background in mathematics or no prior teaching experience might not have been affected in the same way by a mentor observation session as someone with more experience and a greater knowledge of mathematics.

The variability of each new teacher’s school environment could also have been a significant factor in influencing a new teacher’s confidence and performance. Some of the elementary schools have a stronger “mathematics culture” than other schools. For example, in the year of the study three of the elementary schools agreed to meet jointly at least three times by grade level to work on a mathematics vocabulary project. Also, some
schools dedicate more of their building meetings to work on mathematics-focused activities than other schools.

Another limiting factor could have been that a new teacher was enrolled in a graduate mathematics course or mathematics methods course as part of a master’s degree program, which could have represented a threat to internal validity. However, none of the six teachers who were chosen to participate in the study were enrolled that year in graduate level courses.

VIII. Overview of the Study

Chapter 1 has provided an overall introduction to the study. Chapter 2 will provide an overview of the relevant literature that supports and has influenced the direction of the study. Chapter 3 will provide a description of the design of the study. In Chapter 4, the findings of the study will be presented. Chapter 5 will summarize the findings and discuss the findings in light of the theoretical rational and relevant literature, and make recommendations for practice and, possibly, further study.
CHAPTER II
REVIEW OF RELATED LITERATURE

I. Introduction

Given that the focus of this study is a content-based induction program, the two broad areas of relevant literature that will be reviewed in this chapter pertain to teacher quality and induction programs. Both topics are multi-faceted. Regarding teacher quality, the literature on legislative mandates and state requirements, teacher efficacy, and the mathematical knowledge needed for teaching will be reviewed. Regarding induction programs, the areas of review will include the legal and regulatory mandates, characteristics of successful induction programs, effect of induction programs on teacher retention, student achievement and math anxiety, the relationship of successful induction programs to adult learning, professional development for teaching mathematics, and the effect of induction programs on professional learning communities and school culture.

II. TEACHER QUALITY

Legislative Mandates

Since the publication of *A Nation At Risk* (National Commission on Education, 1983), a “seeming endless stream of studies, commissions, and national reports have targeted teacher quality as one the central problems facing schools” (Ingersoll, 2004, p.1). The quest to improve teacher quality in the United States has spawned legislation at both
the state and federal levels to improve the preparation and quality of teachers, as well as, create the means to hold schools accountable for the academic achievement of students. The federal No Child Left Behind Act of 2001 (NCLB) mandates that highly qualified teachers are in every public school classroom by the 2005-2006 school year. The NCLB law defined “highly qualified” teachers as persons with subject matter mastery. What subject matter competencies constitutes “highly qualified” can vary among states. The means by which a state determines “highly qualified” can also vary.

Most states have adopted teacher testing as a means to ensure that only highly qualified teachers obtain licensure (National Conference of State Legislatures, 2005). In Massachusetts, a prospective elementary teacher must have a BA or BS degree and pass two tests (literacy and general curriculum knowledge) in order to receive a preliminary teaching license.

To be eligible for licensure as a Preliminary or initial educator . . . . the candidate shall pass a test established by the board which shall consist of two parts: (A) a reading and writing section which shall demonstrate the communication and literacy skills necessary for effective instruction and improved communication between school and parents; and (B) the subject matter knowledge for the license. [M.G.L. c. 71 s. 38G]

The general curriculum test, which is the second test that elementary teachers must pass, consists of 100 questions (www.doe.mass.edu). Twenty-two of the questions relate to math. Given that only 22% of the competency test questions measure mathematics
knowledge, it is possible that a prospective elementary teacher could fail the math portion of the test and still pass the general curriculum test.

State certification requirements and university teacher preparation programs are responding to the need that elementary teachers have more extensive preparation to teach mathematics. Beginning in 2008, prospective elementary teachers in Massachusetts will be required to pass a separate test in mathematics.

**Teacher Efficacy**

Teachers’ sense of efficacy was identified thirty years ago in a study by the RAND corporation as “one of the few teacher characteristics related to student achievement (Armor et al., 1976). Woolfolk and Hoy (1990) note, “Researchers have found few consistent relationships between characteristics of teachers and the behavior or learning of students. Teachers’ sense of efficacy…is an exception to this general rule” (p.81).

Albert Bandura (1977), who was one of early researchers in the study of human behavior, defines self-efficacy as “beliefs in one’s capabilities to organize and execute the courses of action required to produce given attainments” (p.3). “Self-efficacy beliefs were characterized as the major mediators of our behavior, and importantly, behavioral change” (Henson, 2001, p.3). Over the last thirty years, our understanding of the effect of self-efficacy beliefs on behavior and motivation has been more fully developed.

More recent research into the factors that influence teacher performance highlights the importance of teacher self-beliefs in predicting teacher success. “Teacher efficacy, at the individual and collective level, consistently predicts a host of enabling beliefs,
functional teacher behaviors, and valued student outcomes” (Ross & Bruce, 2007, p.50). Researchers (Goddard, Hoy, & Woolfolk Hoy, 2004; Ross, 1998; Ashton & Webb, 1986) have demonstrated a correlation between teacher efficacy scores and student achievement. “Teachers with high efficacy beliefs generate stronger student achievement than do teachers with lower teacher efficacy” (Ross & Bruce, 2007, p.50). The link between teachers’ self-beliefs and student performance makes sense considering that “the beliefs teachers hold influence their perceptions and judgments, which in turn, affect their behavior in the classroom…” (Pajares, 1992, p.307).

Ashton and Webb (1986) developed an instrument to examine teacher self-efficacy. The instrument includes questions on teaching and personal self-efficacy. Combining the scores with student achievement scores and classroom observations, the researchers found that teachers’ beliefs about instructional efficacy predicted student achievement. Low-efficacy teachers tend to teach mathematics using a model and drill methodology, while high-efficacy teachers tend to focus their instruction on the individual needs of students.

Bandura (1997) found similar results as Ashton and Webb (1986). His research indicates that teachers with high personal confidence (efficacy) have a different instructional style than teachers with low efficacy:

Teachers with a high sense of instruction efficacy operate on the belief that difficult students are teachable through extra effort and appropriate techniques and that they can enlist family supports and overcome negative community influences through
effective teaching. In contrast, teachers who have a low sense of instructional efficacy believe that there is little they can do if students are unmotivated and that they influence teachers can exert on students’ intellectual development is severely limited by unsupportive or oppositional influences from the home and neighborhood environment (p. 240).

The importance of efficacy beliefs has been shown to affect teacher performance in the classroom in other important ways. Allinder (1995) found that teachers with a strong sense of efficacy exhibit greater levels of planning, organization, and enthusiasm. Ross’ (1994) review of 88 teacher efficacy studies found that teachers with higher levels of efficacy are more likely to: (1) learn and try new ideas and strategies in their teaching, (2) use classroom management techniques to promote student autonomy, (3) focus on the needs of low achieving students, (4) promote students’ self-perception of success in learning academic skills, (5) set attainable goals, and (6) persist in helping students who fail. All of these teacher behaviors positively affect student achievement.

Gibson and Dembo (1984) examined the relationship between teacher self-efficacy beliefs, academic focus, and teacher feedback behaviors. They found that teachers with high self-efficacy beliefs engage in practices that relate to high student achievement. They are able to keep all students productively engaged while working with low-achieving students in small groups. They praise low-achieving students more and criticize them less after incorrect answers than teachers with low self-efficacy beliefs.
Guskey (1988) also found instructional behaviors that positively correspond to teacher efficacy, including the amount of time spent on a subject, teaching strategies utilized, and positive feedback to students, all of which could influence students’ efficacy and achievement in a particular subject.

The National Council for Teaching Mathematics (NCTM) states that that one of the goals for teachers is to help students “become confident in their ability to do mathematics” (p. 5). Research results (Henson, 2001; Ross, 1994; Gibson & Dembo, 1984) indicate a positive relationship between teacher self-efficacy and student performance (the ability of students to do mathematics).

Students of teachers with high efficacy scores on the Iowa Test of Basic Skills, the Canadian Achievement Tests, and the Ontario Assessment Instrument tend to outperform students of teachers with lower efficacy scores (Henson, 2001, p 4).

Riggs and Enoch (1990) found that teachers tend to avoid subjects in which they have low efficacy judgments of themselves. The implication for elementary teachers is that they may avoid teaching mathematics or limit the amount of time spent on mathematics if they are not confident about their ability to teach it.

What factors influence teacher efficacy? Bandura (1997) postulates a theory of self-efficacy, which is developed through four types of experiences: mastery, vicarious, social/verbal persuasion, and psychological/emotional arousal. Of these, the most powerful in fostering efficacy is mastery experiences. A mastery experience happens when a teacher is able to demonstrate to herself that she is a competent instructor. Not all feedback or success, however, leads to stronger self-efficacy beliefs. “Attributional
analysis and causal assumptions concerning outcomes impact the interpretation of mastery experiences” (Henson, 2001, p.9). In other words, the value a teacher places upon the source of the feedback or success influences the effect it has on her self-efficacy beliefs.

Which types of mastery experiences are more salient in influencing stronger self-efficacy beliefs? While there is not extensive research that would illuminate the answer to this question, there are a limited number of studies that indicate that teacher efficacy can be impacted by meaningful interventions (Henson, 2001). Ross (1994) found, for example, that eight-month training on cooperative learning strategies resulted in increased teacher efficacy scores, which may indicate that “time” is an important factor in meaningful interventions.

Developing and expanding content knowledge is considered a mastery experience because of the effect on efficacy and competence. Studies have shown that pre-service teachers who take content specific courses in how to teach that subject raise their efficacy scores (Appleton, 1995; Palmer, 2001; Swackhamer et al, 2007). Swackhamer et al. (2007) measured the effect on self-efficacy for two hundred and ninety-seven teachers who took one to four math or science courses over three years at the University of Colorado at Denver’s College of Liberal Arts and Science, School of Education and Human Development through a National Science Foundation funded grant. They found that “increasing the level of content knowledge and demonstrating teaching methods appropriate for conveying this knowledge to a diverse group of students, contributed to an increase in the levels of outcome efficacy” (p.18). Teachers who took the most
courses and had high outcome efficacy scores reported that they appreciated and felt enriched by “the increased content and conceptual understanding of the material through the use of lab exercises, peer interaction, differing approaches to problem solving, and the new curriculum strategies” (p.16).

A second source for increasing efficacy, according to Bandura (1997), is vicarious experiences. Vicarious experiences are those in which someone else models a skill. “The more closely the observer identifies with the model, the stronger will be the impact on efficacy” (Hoy & Spero, 2005). In Swackhamer et al’s (2007) study, the teachers in the high course/high outcome efficacy category felt that the modeling of instructors in hands-on learning was helpful. One teacher said, “The instructors used the inquiry based/hands-on approach to teach us. It allowed for a more thorough understanding of the concepts taught” (p.16).

Ross’ (1994) finding that general teaching efficacy increased after eight months of training on cooperative learning suggests the importance of long-term professional development programs to promote teacher efficacy beliefs.

**Collective Efficacy**

Goddard et al. (2000) extends the theory of personal efficacy to collective teacher efficacy, which they define as “teachers’ beliefs about the collective (not individual) capability of a faculty to influence student achievement; it refers to the perceptions of teachers that the efforts of a faculty of a school will have a positive effect on student achievement” (p.486). The authors found, “Collective teacher efficacy explained 53.27%
and 69.64% of the between-school variance in mathematics and reading, respectively” (p.500). In other words, the culture of individual schools regarding beliefs about mathematics can significantly affect the performance of students on achievement tests.

How does individual self-efficacy affect the collective beliefs in a school?

*The relationship Between Collective and Individual Efficacy*

Collective efficacy can be measured by either the sum of individual faculty efficacy scores or by the combined score of the perceptions of individuals regarding the capabilities of the entire faculty in a school. Which is a better measure? Bandura (1997) suggests that the answer to that question depends upon the level of organizational coupling present. Organizations which are very interdependent (tight coupling) would best use the sum of the individual perceptions, while loosely coupled organizations could use the aggregate of individual efficacy scores. The question then is whether an elementary school is a loosely or tightly organized institution? Most elementary schools tend toward the loosely organized (which is why isolation is common problem in many schools). The more loosely organized, the greater the effect of individual efficacy beliefs becomes on the success of the whole. Therefore, teachers with high levels of self-efficacy in a loosely organized school may be able to influence the success of teachers with lower levels of self-efficacy and, thus, the performance of students.

Given the significance of teacher efficacy beliefs on student achievement, how are self-beliefs impacted? Bandura (1997) proposed that changes in self-efficacy are the
result of “compelling feedback that forcefully disrupts the preexisting disbelief in one’s capabilities” (p.82). While Hoy and Woolfolk (1990) found that efficacy is more easily influenced in preservice years, efficacy tends to be resistant to change for more veteran teachers (Tschannen-Moran et al, 1998) because “it is an internally held belief about oneself that solidifies with experience and time (Henson, 2001, p.12). As mentioned earlier, long-term professional development programs can have a positive effect on self-efficacy (Ross, 1994), particularly if the teacher faithfully implements the change in her classroom successfully. Professional development programs, therefore, which provide long-term instruction in effective teaching techniques that are implemented in the classroom, offer teachers the opportunity for mastery experiences, which should increase the likelihood of increased self-efficacy (Ross, 2007).

Ross and Bruce (2007) examined the effect of a multiple session professional development program in which presenters modeled specific aspects of standards-based mathematics teaching to sixth grade teachers. “After each session, teachers applied the teaching principles in their own classrooms, collected artifacts which reflected student thinking, and shared their experience with colleagues at the next session” (Ross & Bruce, 2007, p.54). The strategy behind the professional development program was to increase opportunities for teacher mastery experiences in order to strengthen competence. The elements of the program included:

(a) active teacher learning, (b) examples from classroom practice, (c) collaborative activities modeling effective pedagogy, (d) opportunities for reflection, (e) practice
and feedback, and (f) focus on content. By increasing competence, we anticipated that teachers would be more successful in the classroom, according to teachers’ usual criteria (e.g. student responsiveness to teacher prompts), which would enhance teacher efficacy (p. 54).

Following Bandura’s (1997) theoretical model for how efficacy beliefs are developed (mastery experiences, vicarious experiences, social/verbal persuasion and psychological/emotional arousal), Ross and Bruce’s (2007) commented on how the professional development program provided vicarious experiences for teachers that increased their teacher efficacy:

Teacher efficacy increases when teachers observe their peers bringing about student learning. As our first strategy, we enlisted experienced teachers from the same district to demonstrate new practices because models are more credible when they share characteristics with the learners. As our second strategy, we structured the debriefing sessions (through a series of prompts given to pairs and groups of four) to highlight classroom success so that teachers would perceive their peers as being successful. As our third strategy, we presented evidence to demonstrate that standards-based teaching could be implemented by generalist teachers and that doing so leads to higher student achievement (p. 54).

Another embedded strategy in the professional development program included redefining a “successful lesson” from one where most of the students gave the correct answer using a standard algorithm to a lesson where students demonstrated conceptual
understanding, participated in the construction of their knowledge, and communicated their knowledge. The rubric teachers used to judge the lesson contained 10 standards of mathematical teaching (Ross & Bruce, 2007).

To maximize effectiveness, Ross and Bruce incorporated social/verbal persuasion and psychological/emotional arousal (from Bandura’s theory of efficacy development) to promote efficacy. Teachers were reassured regularly that they could be successful. Stress and anxiety were reduced by sequencing the activities from least threatening (use of manipulatives) to most threatening (sharing control of the lesson with students) (Ross & Bruce, 2007).

In this study, there was a control group of teachers who did not participate in the professional development program. Both groups were surveyed about their confidence in implementing the new standards-based mathematics program in their classroom. In comparing the two groups, Ross and Bruce (2007) found that “the results were statistically significant only for teachers’ confidence in managing students” (p. 58). However, given that teaching a standards-based mathematics curriculum poses many challenges with respect to managing student explorations to develop conceptual knowledge, this finding is significant. Ross and Bruce (2007) concluded:

The practical implications of our study suggest directions for PD [professional development]. Presently, PD for mathematics teachers focuses on the acquisition of instructional skills, a necessary but not sufficient condition for improved teaching. Our research indicates that explicit attention to teacher cognitions,
particularly, teacher beliefs about their capacity to bring about student learning in the standards-based mathematics curriculum, is an essential complement to skill acquisition….Our results indicate that PD that addresses sources of efficacy can contribute to creating more confident teachers (p.59).

Mathematics Content and Pedagogical Knowledge

The Massachusetts’ Department of Education (DOE) proposes in their Guidelines for the Mathematical Preparation of Elementary Teachers (2007) that prospective elementary teachers must demonstrate conceptual competency in mathematics in the following areas:

- Numbers and operations
- Functions and algebra
- Geometry and measurement
- Data analysis, statistics and probability

These areas of conceptual knowledge correspond to the major categories in the Massachusetts Mathematics Curriculum Frameworks, as well as, the National Council of Teachers of Mathematics’ (NCTM) (2000) Principles and Standards for School Mathematics.

The Department of Education (DOE) Guidelines for the Mathematical Preparation of Elementary Teachers also states that in addition to demonstrating knowledge of fundamental computation skills and a comprehensive, in-depth understanding of K-8
mathematics, elementary teachers are required to demonstrate “that they understand and can explain to students, in multiple ways, why it makes sense” (603 CMR 7.06(7)(b)).

According to Ball (2003), the goal of teacher education programs in mathematics is not to produce teachers who know mathematics, but rather to improve student learning in mathematics. Deborah Loewenberg Ball (2003) states, “teachers’ opportunities to learn must equip them with the mathematical knowledge and skill that will enable them to teach mathematics effectively” (p.1). She contends that simply knowing mathematical concepts that relate to curriculum standards misses the mark of what is also essential for competent teaching:

An adequate portrait of the mathematical knowledge needed for effective instruction depends on the analysis of the work of teaching. What do teachers do with mathematics in the course of their work? In what sorts of mathematical reasoning do they engage regularly” What kinds of mathematical problems do the regularly face? Without such examination of the mathematical demands of teaching, ideas about what teachers need to know are likely to underestimate and misestimate what is entailed (p.1).

Ball (2003) goes onto say, “Teaching requires justifying, explaining, analyzing errors, generalizing, and defining. It requires knowing ideas and procedures in detail, and knowing them well enough to represent and explain them skillfully in more than one way. This is mathematics” (p.3). Teaching mathematics entails:
• Respect for the integrity of the discipline – which involves understanding that mathematical procedures are reasoned and the efficiency and meaningfulness of those procedures are deeply intertwined. It also involves an understanding that at the core of mathematics is whether an idea is generalizable.

• Knowledge of mathematics that is sufficient for the teacher to be able to “unpack ideas and make them accessible as they are first encountered by the learner” (p.4).

• Knowledge of mathematics as reasoned. Teachers must understand “why procedures work, that certain procedures are true, that particular relationships exist, and on what basis” (p. 4).

• Knowledge of fundamental mathematical connections. For example, “teaching multi-digit multiplication will depend on an appreciation of its foundations in place value, its geometric representations, and its connections to work with polynomials in algebra” (p.4). Teachers must understand how ideas can be structured and connected.

Ball (2008) strongly advocates the need for initial and continuing teacher education to help prepare “ordinary people” to be effective mathematics teachers in elementary schools. She contends that the work of teaching is “unnatural” as opposed to the common ‘ways of being’. Effective mathematics teachers, for example, probe student ideas as opposed to assuming that you know what students mean; effective teachers provoke disequilibrium and error instead of correcting and smoothing over mistakes;
effective teacher listen, watch, and help students ‘do’ instead of telling, showing, and ‘doing for’ students. With regard to the task of teaching students multiplication, for example, Ball, Hill, and Bass (2005) state:

Clearly, being able to multiply correctly is essential knowledge for teaching multiplication to students. But, it is also insufficient for teaching. Teachers do not merely do problems while students watch. They must explain, listen, and examine student work. They must choose useful problems or examples. Doing these things requires additional mathematical insight and understanding (p.4)….Further, it indicates that there are predictable and recurrent tasks that teachers face that are deeply entwined with mathematics and mathematical reasoning – figuring out where a student has gone wrong (error analysis), explaining the basis for an algorithm in words that children can understand and showing why it works (principled knowledge of algorithms and mathematical reasoning), and using mathematical representations. Important to note is that each of these common tasks of teaching involves mathematical reasoning as much as it does pedagogical thinking (p. 6).

Ball (2008) states that it is important to see “teaching as skilled, high precision work that is not a matter of personal style and preference and acknowledge its professional nature without repudiating its ‘creativity’” (presentation at NCSM, March, 2008). Therefore, a reliable system of preparing many ordinary people for the expert practice of teaching mathematics is needed.
Ball (2008) outlines the challenges facing educators in making ‘ordinary people’ expert mathematics teachers:

- Stay focused on the mathematics, and not just on how to teach mathematics.
- Develop a practice-based theory of Mathematical Knowledge for Teaching (i.e. habits of mind, concepts and skills).
- Unpack the mathematics sufficiently and convincingly to help teachers see what there is to learn and do.
- Make visible the connections to the kinds of mathematical thinking, judgment, reasoning a teacher must do in teaching.

Liping Ma (1999) asserts that to be an effective elementary mathematics teacher, content knowledge cannot really be separated from knowledge of math pedagogy and knowledge of how students learn math. Ma describes effective teacher training in mathematics as teachers acquiring a “profound understanding of fundamental mathematics” (PUFM). Ma explains that a teacher with PUFM “goes beyond being able to compute correctly and to give a rationale for computational algorithms” (p. xxiv). A PUFM teacher is “not only aware of the conceptual structure and basic attitudes of mathematics inherent in elementary mathematics, but is able to teach them to students” (p. xxiv). There is fundamental agreement between Ma and Ball that subject matter knowledge and pedagogical knowledge are both essential for elementary teachers. They
share similar views on the important characteristics of effective elementary mathematics teaching.

Ma (1999) contends that the characteristics of a PUFM teacher are:

- **Connectedness** – the teacher is able to make connections between the concepts and procedures that students are learning. These teachers present a “unified body of knowledge” (p.122).

- **Multiple Perspectives** – the teacher is able understand, elicit, and demonstrate multiple solutions to a problem, as well as, articulate the advantages and disadvantages to a particular method. The teacher encourages flexible understanding of mathematical concepts and procedures.

- **Basic ideas** – the teacher emphasizes basic ideas and attitudes in mathematics, such as, a single example does not constitute a proof of an idea.

- **Longitudinal coherence** – the teacher is aware of the entire elementary mathematics curriculum, as well as, the connection of elementary mathematics to more advanced mathematics. The teacher is aware of what students already know and will build the foundation for the mathematics the students will learn in subsequent grades.
Ball (2003) when addressing the question of what mathematical knowledge and skills are essential for elementary teachers divides her prescription into two categories: knowledge of mathematical concepts and practices and dispositions.

Mathematical knowledge:

- Concepts of number and place value notation
- Operations
- Number theory and number systems
- Common algorithms and how and why they work
- Concepts and tools of algebra
- Geometric concepts and reasoning
- Concepts and tools of statistics and probability

Practices and Dispositions:

- Represent and connect representations (e.g. symbols, graphs, geometric models)
- Use precise mathematical language and definitions
- Provide mathematical reasoning and justification
- Foster good sense about mathematical precision
- Encourage mathematical curiosity and interest

Ball (2003) explains that teachers “need to know the same thing that we would want any educated member of our society to know, but much more. That “more” is not
the more of more conventional mathematics coursework. It is the “more” of more understanding of the insides of ideas, their roots and connections, their reasons and ways of being represented” (p.6). The mathematical knowledge for teaching is different from other mathematically intensive occupations:

Interpreting someone else’s error, representing ideas to multiple forms, developing alternative explanations, choosing a usable definition – these are all examples of the problems that teachers must solve…The mathematical knowledge needed for teaching must be usable for those problems. Mathematical knowledge for teaching must be serviceable for the mathematical work that teaching entails, from offering clear explanations to posing good problems to students, to mapping across alternative models, to examining instructional materials with a keen and critical mathematical eye, to modifying or correcting inaccurate or incorrect expositions. The mathematical knowledge needed for teaching even at the elementary level, is not a watered-down version of “real” mathematics. Teaching mathematics is a serious and demanding arena of mathematical work (p.6).

Hill, Rowan, and Ball (2005) investigated the relationship between mathematics knowledge and student achievement. In their study, 700 first and third grade teachers were administered a test, which covered both common and specialized mathematics content knowledge. Their students (3,000) were administered the Terra Nova (a reliable standardized test) at the beginning and end of the school year. The students’ gains were compared to their teachers’ scores on the mathematics test. Controlling for variations of
several variables (absentee rate, length of mathematics lessons, teacher credentials and experience), they found that teachers’ mathematics content knowledge positively predicted improved student performance on the Terra Nova. Their study supports the importance and affect of teachers’ content knowledge on student achievement.

III. Induction Programs

Legal Mandates

In Massachusetts, the legislation regarding teacher induction programs is very specific. The 1993 Education Reform Act [Chapter 71, Section 38G] and the Massachusetts Regulations for Educator Licensure [603 CMR 7.00] require districts to provide a system of support for beginning educators in the form of an induction program.

“The plan shall, to the extent feasible, be designed to fulfill all planning requirements of state and federal education laws, and shall include, but not be limited to: (a) an analysis of student and subgroup achievement gaps in core subjects; (b) identification of specific improvement objectives; (c) a description of the strategic initiatives the district will undertake to achieve improvement objectives, and (d) performance benchmarks and processes for evaluating the effect of district improvement initiatives. Also, the plan shall describe the professional development activities that will support each district improvement initiative and the teacher induction and mentoring activities that will be
undertaken to support successful implementation of the district's improvement efforts.” (69 section 1)

The regulations link licensure and induction programs by making participation in such a program one of the requirements for the Professional License (MA Department of Education). Consequently, districts need to provide an induction program for educators in their first year of teaching. The regulations also describe the components that every Massachusetts’ induction program should have, which include orientation programs, mentoring relationships, professional development, evaluation, and support teams.

The goal of these regulations is to provide a structured program to help new teachers improve their practice, while at the same time creating opportunities for veteran teachers to reflect upon their practice. Induction programs have the potential of creating collaborative learning communities within a school. “These benefits can lead to a much higher rate of retention, as new educators find themselves in an environment that cultivates continual growth and success” (MA DOE Teacher Induction Programs).

Characteristics of Comprehensive Induction Programs

Comprehensive induction programs include most, if not all, of the following characteristics:

- School and district orientation programs.
- Mentoring relationships, which include observations, co-teaching, and joint lesson planning with release time granted for these activities.
• Individualized plans for growth and development.

• Support teams with veteran teachers including regular opportunities to observe and be observed by other teachers.

• Workshops and training for both new teachers and mentors.

• Formal evaluation by a supervisor to gain an understanding of strengths and weaknesses.

• Modified teaching schedule or assignments in which teachers receive smaller loads, fewer preps, or less difficult classes.

• Opportunities to participate in professional learning communities.

(www.doe.mass.edu; www.nwrel.org)

All of the above descriptors for effective induction programs, which are outlined in the Massachusetts’ Department of Education’s regulations, parallel the recommendations found in research studies and the requirements of exemplar programs such as The Santa Cruz New Teacher Project, Connecticut’s Beginning Teacher and Support and Training Program, Lawrence, MA New Teacher Mentor Program, and Boston, MA’s New Teacher’s Residency Program.

**Promising Induction Programs**

Nationwide, there are a number of exemplary induction programs, as measured by their retention rates and scope. Each program mentioned below is considered a comprehensive induction program. Yet, nonetheless, each contains unique features.
The Santa Cruz New Teacher Project (SCNTP), the longest running formal induction program in California, extends the induction experience to two years. Mentors meet weekly with their mentee for two hours either during, before, or after school. Mentors will co-teach lessons, and do demonstration lessons. New teachers meet monthly to discuss their problems and share successes. Mentors (advisors) also gather data to assess new teacher progress on the “Developmental Commission of Teaching Abilities”, which was created by the project and is aligned with California’s Standards for teaching progress (Moir, Gless, & Barron, 1999, as cited in Feiman-Nemser).

“Formative assessment is a central feature of California’s Beginning Teacher Support and Assessment Program (BTSA)” (Feiman-Nemser, 2001, p.1036). New teachers’ strengths and “areas of growth” are identified through a formative assessment process. Using the data, an Individual Learning Plan is developed “that identifies professional development activities to improve the new teacher’s knowledge and practice” (Feiman-Nemser, 2005, p.1036). After one year of teaching, the retention rates in California districts using the BTSA program ranged from 80 to 89 percent, as compared to 46% in districts not using BTSA (Strong, 2005, p.190).

Connecticut’s Beginning Teacher and Support and Training Program (BEST) is similar to California’s BTSA, except that Connecticut also has summative assessments in each of the first three years of teaching. “Second year teachers compile a portfolio that is assessed by trained assessors using the content-specific professional teaching standards. When beginning teachers meet the acceptable standard, they are recommended for
provisional certification” (Feiman-Nemser, 2005, p.1036). Connecticut has similar retention rates as California districts using BTSA.

In Massachusetts, one of the most successful induction programs in reducing attrition rates operates in the Lawrence Public Schools, which is one of the poorest and lowest-performing school districts in the state. In contrast to the national average of 40 to 50 percent retention after three years, Lawrence had 85% of its new teachers return in 2002-2003. After three years, 62% of the teachers were still teaching in the district, which is 12% higher than the national average. Mentors work with new teachers for three years. First year teachers attend regular strategy session workshops facilitated by education school professors or district mentors. Teachers in these workshops (support groups) have the opportunity to discuss specific issues/concerns that they have with regard to any aspect of their practice.

Boston recently initiated an induction program called the Boston Teacher Residency (BTR). Unlike the Lawrence program, BTR is a selective program – teachers must apply to enter the program. The Boston Teacher Residency (BTR) program is part of Boston’s strategy to improve instruction for every child:

BTR recruits talented, committed people to make a difference in the city’s classrooms. During the 13-month program, Teacher Residents work side-by-side with Mentor Teachers in Boston’s public schools and take a specialized curriculum developed and led by local educators and community leaders. BTR graduates earn a Massachusetts Initial Teacher License, a master’s degree in education from
UMass/Boston, and credit toward a dual license in special education….Since graduating its first class in 2004, BTR has prepared over 200 like-minded, effective teachers who are raising the bar in their schools and across an entire school system. BTR intentionally clusters its graduates in schools throughout the city, where they can work together to create the greatest impact.

http://www.bpe.org/btr?gclid=CLKqy-XpgJkCFQECGgodE14K1g

To date, BTS retains only about 53% of its new teachers after three years, which is not significantly different from the national retention percentages for urban districts (Boston Teacher Residency Fact Sheet).

From a study of nine state induction programs, Grant (2004) found, “the presence of an induction and mentoring program had a statistically significant effect on teacher retention, as did the quality of the program and its location (as cited in Strong, 2005, p.190).

**Effect on Teacher Retention**

Public schools in the United States are experiencing serious teacher retention problems, as well as, the possibility of a teacher shortage in the next five years (The Boston Globe, 2007). “Nearly forty percent of teachers leave the profession within their first five years of teaching” (Ingersoll, 2001). The potential shortage is due to the combined factors of teachers who are retiring and those who are leaving the profession
after only a few years. There is considerable research on the variables that contribute to teacher dropout, as well as, the influences that support teacher retention.

Ingersoll (2001) found that teachers left the profession because of salaries, lack of administrative support, student discipline issues, lack of student motivation, and a lack of voice in decision-making. Strong (2005) reporting on the findings of several studies indicates that stress is another powerful factor that motivates teacher attrition. Stress can result from working conditions, lack of self-efficacy and satisfaction, or lack of positive feedback from colleagues and principals.

Research shows that attrition rates improve when new teachers are provided with a comprehensive induction program, as distinguished from a mentoring program in which the new teacher is assigned a veteran teacher to help her adjust to the new school culture (Ingersoll, 2001). Strong (2005) in his study of 72 teachers who had been given a comprehensive induction program found that 88% of these teachers were still teaching six years later, though not necessarily in the school or district in which they had been trained. Districts with exemplar inductions programs in Massachusetts and elsewhere have experienced similar results.

As previously discussed, Lawrence Public School’s five-year old Mentoring/Induction Program has positively transformed its retention rate to 85 percent from 50 percent in 1999-2000 (The Boston Globe, March 29, 2007). The California BTSA system has enjoyed similar retention rates of 85% for their new teachers (Strong, 2005, p.190).
Not all induction programs include all of the recommended components. Ingersoll and Smith’s study (2003) found that induction programs, which included collaboration and common planning time, considerably improved attrition rates of new teachers. If the teachers received a “basic induction” program, which included mentoring and administrative support, the attrition rate was 39%, but if the induction program was more comprehensive and included collaboration, seminars, and networking, the attrition rate went down to 18%.

Much has been written about the isolation of teachers in schools. Yet, in 2001, teachers ranked “cooperative, competent teacher colleagues/mentors” as the single most important factor in supporting them in their work (NEA, 2003, p. 73). Kardos and Johnson’s (2007) study of the responses of 486 new teachers in four states to a randomly distributed survey found a strong positive correlation between new teachers’ satisfaction with teaching and their reports about working in schools that had a high level of collaboration and contact with teachers of all experience levels. They did not find any statistical relationship between satisfaction and one-to-one mentoring.

**Effect on Student Achievement**

While there are no peer-reviewed studies that directly link induction programs with student achievement, there are many studies which have established a positive correlation between teacher self-efficacy and student achievement. There are also studies which have positively linked teacher self-efficacy with supportive mentoring programs in their first years of teaching.
The research work of Bandura (1997) and others suggest that a teacher’s sense of efficacy can be affected more in her earlier years of teaching than later years. Bandura (1997) found that the level of support a teacher had in her first year of teaching correlated positively with self-efficacy. Friedman (2000) found that those who experienced “shattered dreams of idealistic performance” pointed to criticisms from colleagues, isolation, work overload, lack of recognition or reward, and inappropriate initial teacher training as sources of stress and threats to efficacy.

Hoy and Spero (2005) conducted a longitudinal study of 53 elementary teachers that “assessed the efficacy of prospective and novice teachers at the beginning of their preparation, at the end of student teaching, and after their first year of teaching” using four protocols for measuring self-efficacy (p.348). Four quantitative measurements of teacher efficacy were used, including Bandura’s assessment of Instructional Efficacy scale, Gibson and Dembo’s Teacher Efficacy scales, and an instrument to reflect the specific context and goals of the preparatory program. The purpose of using four measurements of efficacy was to increase the confidence of the study.

They found that teacher efficacy did change for teachers over the course of their pre-service program, student teaching, and first year of teaching. “Results indicated significant increases in efficacy during student teaching, but significant declines during the first year of teaching. Changes in efficacy during the first year of teaching were related to the level of support received” (Hoy & Spero, 2005, p.355).

Hoy and Spero (2005) found that all four measures of efficacy revealed the same pattern that efficacy rose during teacher preparation and student teaching but declined
after the first year of teaching. The data in this study reveals the fragility of self-efficacy when a teacher is fully responsible for a class for the first time, underscoring the importance of induction programs as a means of supporting new teachers.

Darling-Hammond (1999) concluded in her study of state policies on teacher quality and student achievement:

States interested in improving student achievement may be well-advised to attend, at least in part, to the preparation and qualifications of the teachers they hire and retain in the profession….This research indicates that the effects of well-prepared teachers on student achievement can be stronger than the influences of student background factors (p.38-39).

A well-prepared teacher is not only a teacher who enters the field with strong academic credentials, but who is also supported in her early years of teaching with appropriate programs of professional development.

Because there are no research studies directly relating student achievement and induction programs, the U.S. Department of Education has commissioned a study to investigate the relationship between induction programs and student achievement, which will be published sometime in 2008.
Effect on Math Anxiety

Over the last two decades, the phenomenon of “math anxiety” in adults has been a much researched topic by both mathematics educators and educational psychologists. Mathematics anxiety has been defined as “a state of discomfort, which occurs in response to situations involving mathematical tasks, which are perceived as threatening to self esteem” (Trujillo & Hadfield, 1999, p.1). The reaction can involve a sense of panic, tension, fear, sweaty hands, nervous stomach, difficulty breathing, or inability to concentrate. While the numbers of people who experience these reactions are relatively few, the number of elementary teachers who experience these reactions is disproportionately large (Levine, 1996), which is a source of concern given their responsibility for teaching young children mathematics.

Bursal and Paznokas (2006) examined the relationship between teachers’ mathematics anxiety and their confidence to teach elementary mathematics. Sixty-five preservice elementary teachers were administered Busal and Paznokas’ Revised Mathematics Anxiety Survey (R-MANX) along with questions from the Mathematics Teaching Efficacy Beliefs Instrument (MTEBI) (Enoch, Smith, & Huinker, 2000) and the Science Teaching Efficacy Beliefs Instrument (STEBI-B) (Riggs & Enoch, 1990). They found that teachers who had high mathematics anxiety had low confidence in teaching elementary mathematics.

Hadfield and McNeil (1994) identified three sources of mathematics anxiety: environmental, intellectual, and personality factors. Environmental factors include negative experiences in the classroom such as belittling, rigid presentations, lack of
participation, parental pressure, and insensitive teachers. Intellectual factors include, but are not limited to, lack of confidence in mathematical ability and/or persistence; mismatched teaching and learning styles; or, a disability such as dyslexia. Personality factors include shyness, reluctance to ask questions, or gender intimidation (Trujillo & Hadfield, 1999; Levine, 1996).

Trujillo and Hadfield (1999) in their study of 50 preservice elementary teachers found that “negative classroom experiences in mathematics and lack of support at home combined with an anxiety toward testing will yield a mathematically anxious individual” (p.9). They proposed several solutions to the problem including mathematics anxiety clinics where individuals examine the source of their anxiety or an exemption to teach mathematics for mathematically anxious individuals.. They felt, however, that “the most practical solution is to provide elementary mathematics methods courses and professional development opportunities that reduce mathematics anxiety through the development and delivery of cutting edge lessons in mathematics for elementary school children” (p.10).

Levine (1996) found that mathematics methods courses improved not only competence but helped reduce anxiety. By extension, induction programs that include mathematics pedagogical support should help new teachers reduce their anxiety about teaching mathematics.

**Relationship of Successful Induction Programs to Adult Learning**

The components and structure of successful induction programs are informed by research on adult learning. Malcolm Knowles (1989), who is considered to be one of the
most influential researchers in the area of adult education theory, proposes that adults have a need to be self-directed in their learning. Adult learners bring both extensive background experience and knowledge to their learning and use experience as their main resource. Adult learners want to apply what they have learned to their personal and professional lives. Therefore, they need to know why they are learning something before they learn it. As a result, adult learners tend to respond more to intrinsic motivators than extrinsic motivators.

In designing mentoring programs, English (1999) suggests the importance of involving mentors and mentees in program design and “engaging their interest from the very beginning” (p. 196). In doing so, program planners demonstrate their respect for adult learners:

Needs assessment is a way of treating mentors and mentees as subjects of their own learning, rather than as objects. On a practical level, this may mean asking mentors if they need additional skills in areas such as communication and supervision of mentees before the preparation topics are decided upon…Mentees need to be made aware from the beginning that there are expectations and benefits for them in mentorship, and that continuing education is an integral part of the teaching profession (p.196-97).

For both mentors and mentees it is important that they are aware of why they are engaged in professional development programs.
Neo-Piagetian theory and research, which is based on Piaget’s work, provides promising guidelines to help educators plan learning opportunities for adult learners. The *why* of what new teachers need to know is fairly clear in the context of the expectations and standards of student learning and achievement for which they are held accountable. The growing expectation for increased pedagogical knowledge and skills has created pressure within the teaching profession for targeted and effective professional development to help teachers master new knowledge.

While neo-Piagetian theory still refers to stages of cognitive development, it departs from classic Piagetian theory in how learners assimilate knowledge. Knight and Sutton (2004) make the contrast:

> In classic Piagetian theory, development is considered a transformation, or ‘accommodation’ of new content into existing structures. Recent research has demonstrated that such a simple distinction between learning and development is no longer viable, since learning involves changes in cognitive organization and structure, as does development…Advanced adult thinkers are believed not only to understand and reflect on complex systems of abstract ideas, but also to consider their role as individuals in interpreting and interacting with these systems of abstract ideas (pp. 50-51).

One of the implications of this finding is the importance of contextual factors in cognitive functioning. Piaget acknowledged the importance of environment in his work,
but proposed that despite a range of environments, learners progress through the same sequence of stages regardless of the characteristics of a specific environment. Neo-Piagetians, responding to more recent research on learning, however, have concluded that learning and development varies across different environments and is very dependent upon context (Knight & Sutton, 2004). As a result:

Neo-Piagetians typically consider co-constructive processes involving the collaborative efforts of two or more learners to be vital to complex, integrated learning and development, and as central to the development of new learning in adults as it is in children. Moreover, these learning processes are contextually sensitive in that new learning is most robust in the context in which it is constructed. Conversely, as learning context and processes vary from the original one, new learning becomes increasingly fragile and potentially difficult to access at all at times (Knight & Sutton, 2004, p. 51).

The implication of this finding, when applied to professional development for new teachers, is that it is a more transforming experience to provide opportunities to learn pedagogical skills in a classroom setting than in a workshop or unrelated setting. Concepts and skills learned through classroom observations and practice are more robust and longer lasting than those learned in non-related contextual settings.

Oji (1980) who studied adult learners in teacher in-service programs identified four important characteristics for successful adult learning:
• Concrete experiences that are transferable to their teaching.

• Available resources for supervision and advising.

• Encouragement and opportunities to assume new and complex roles.

• Support and feedback when implementing new programs and strategies.

Trotter (2006) found that teachers like professional development programs that provide opportunities to discuss teaching practices with colleagues and to problem-solve challenging classroom situations.

Recent research on the cognitive development of adults suggests that there is a relationship between the complexity of cognitive development and the ability to “function in more humane and democratic modes than those at less complex stages” (Sprinthall & Thies-Sprinthall, 1983, p.18). People scoring at higher levels of cognitive complexity tend to be more flexible, empathetic, and responsive in their relationships with other people. Similarly, teachers with high conceptual level scores are described in a similar manner. As teachers, they employ a variety of teaching strategies to respond to the needs of their students (Sprinthall & Thies-Sprinthall, 1983).

Gage (1978) calls this adaptive type of teaching “indirect teaching”. He found that students of teachers who had a higher ratio of indirect teaching to direct teaching performed academically better than students whose teachers had a lower ratio. In teaching mathematics, teachers are only able to be flexibly responsive to the learning needs of their students if their conceptual understanding of mathematics is broad and deep and they have learned teaching strategies to support a range of learners.
Professional Development for Teaching Mathematics

What are the components of an effective professional development/induction program for teaching elementary mathematics? Given the minimal preparation most new elementary teachers have for teaching mathematics (Ball, 2008), an induction program should provide opportunities to improve new teachers’ mathematics content knowledge and pedagogical skills, thereby, helping them to effectively nurture the mathematical proficiency of their students. “Mathematical proficiency refers to the goals of successful mathematics instruction reflected in these five interdependent strands: conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, and productive disposition” (NRC, 2001).

Timmerman (2004) in her study of interventions that impact prospective elementary teachers’ beliefs about teaching mathematics concludes:

When mathematics teacher educators provide prospective teachers with opportunities to learn how to contribute to and implement the strands of mathematical proficiency, prospective teachers are obligated to confront their existing beliefs, knowledge, and abilities about what it means to know and do mathematics, how children learn mathematics, and strategies for teaching mathematics (p.369).

This statement suggests that when the focus of mathematics induction programs is the development of teachers’ pedagogical skills, an extended benefit is that teachers’
knowledge of mathematics will also deepen through the experience as well as their understanding of how children learn mathematics.

Loucks-Horseley et al. (1996) expresses a shared vision of many mathematics educators that the best professional development experiences include the following principles:

1. They are driven by a clear, well-defined image of effective classroom learning and teaching of mathematics.

2. They provide teachers with opportunities to develop knowledge and skills and broaden their teaching approaches, so that they can create better learning opportunities for students.

3. They use instructional methods to promote learning for adults, which mirror the methods to be used with students.

4. They build the learning communities of mathematics teachers.

5. They prepare and support teachers to serve in leadership roles.

6. They consciously provide links to other parts of the education system (i.e. align with curriculum frameworks and assessments).

7. They include continuous assessment.

Ball and Cohen (1999) describe these principles of professional development as “learning in practice”, which “at the core is about learning professional performance”. To be relevant to teacher development “professionals need experience with the tasks and ways of thinking that are fundamental to the practice…such experiences must be
sufficiently distanced to be open to careful scrutiny, unpacking, reconstruction, and the like” (p.12). “Professional learning must be centered in the central activities of the profession, that is, in and about the practices of teaching and learning” (p.13).

Reflection and discourse about practice are also key elements of an effective professional development program. Ball and Cohen (1999) also acknowledge the importance of cultivating content knowledge and skills through the professional learning activities, which include reflective discourse about best practices.

In a study of three interventions on prospective teachers’ beliefs about the knowledge base needed for teaching mathematics, Timmerman (2004) found that peer teaching, which involved teachers critically analyzing student-teacher interactions in order to justify their teaching practice, was a successful intervention in helping the teachers understand the mathematical knowledge needed to teach for mathematical proficiency. “The peer teaching intervention established the opportunity to learn, in which the prospective teachers contributed to each other’s learning by reflecting on and verbalizing individual interpretations of the mathematical content taught and teaching practices of each lesson” (p.373).

What can be learned from the literature on self-efficacy, induction programs, adult learning, and content-based professional development is that in designing an induction program for new teachers in a particular discipline it is important the participants improve their own sense of self-efficacy and knowledge of the discipline through learning activities that are centered in the classroom. Feiman-Nemser (2001) concurs:
New teachers need a compelling vision of good teaching and a beginning repertoire of approaches to curriculum, instruction, and assessment consistent with the vision. A major task of induction is helping new teachers enact these approaches purposefully with their students by developing the necessary understanding and flexibility of response (p.1029).

**Effect of Induction Programs on Professional Learning Communities and School Culture**

Schools and districts that support mentorship/induction programs benefit by building leadership capacity. Central to most school improvement plans in recent years is the development of professional learning communities. “The term ‘professional learning community’ is one that implies a commitment not only to teacher sharing but also the generation of a school-wide culture that makes collaboration expected” (Harris, 2003, p. 321). Much is known about the benefit of professional learning communities on teacher development, thus, student achievement. The issue is how these learning communities develop and flourish. In professional learning communities “teachers participate in decision-making, have a shared sense of purpose, engage in collaborative work and accept joint responsibility for the outcomes of their work” (Harris, 2003, p.321).

Frost and Durrant (2003) note, “It is not a matter of delegation, direction or distribution of responsibility but rather a matter of teacher agency and their choice in
initiating and sustaining change” (p.174), which is why building teacher leadership capacity is essential to the sustainability of professional learning communities.

There is a circular relationship between teacher leadership and professional learning communities. While teacher leadership is necessary to sustain professional learning communities, professional learning communities (e.g. collaborative schools) foster teacher leadership. Judith Warren Little (1982) found in her study of six urban schools:

The status of an actor both ascribed (e.g. position) and achieved (a reputation of a master teacher) tends to govern the rights of the actor to initiate and to participate in collegial experimentation. In some schools, such rights are limited to principals, department chairs, and some influential teachers. In the more successful and adaptable schools, rights to initiate and participate are more widely distributed, rely less on formal position and are variable by situation (p.337).

Little (1982) found a strong relationship between successful schools (as defined by student achievement) and teacher collaboration. She also found that schools where leadership was more distributed were also more collaborative. Little identified four characteristics of collaborative schools in which administrators and teachers work together to improve teaching and learning:

- Teachers engage in frequent, continuous, and concrete talk about their teaching practices.
• Teachers are frequently observed and given feedback about their teaching.
• Teachers plan, review assessments, and prepare lessons and materials together.
• Teachers teach each other the practice of teaching.

All four characteristics of collaborative and successful schools parallel the qualities of effective new teacher induction programs.

**Distributed Leadership**

In the literature there is variability on the definition, theories, and models of school leadership. However, an emerging idea in recent literature is that effective leadership need not equate with role or position (Harris, 2003; Silns & Mulford, 2002; Spillane et al., 2004; Frost & Durrant, 2003). Harris (2003) states, “Leadership can be separated from person, role and status and is primarily concerned with the relationship and the connections among individuals within a school” (p.318). A distributed view of leadership “incorporates the activities of multiple groups of individuals in a school who work at guiding and mobilizing staff in the instructional process of change” (Spillane et al., 2004, p.16).

Harris (2003) states:

While distributed leadership does not equate with ‘delegation’, it also does not represent a form of leadership that is so diffuse that it loses its distinctive qualities. It is clear that certain tasks and functions would have to be retained by
those in formal leadership positions but that the key to successful leadership resides in the involvement of teachers in collectively guiding and shaping instructional development (p.319).

Distributed leadership is about interdependency rather than dependency in the way teachers share responsibilities within a school (Spillane et al., 2004; Harris, 2003). In a distributed leadership model the responsibility for improved teaching and learning is not delegated by the principal but assumed by the teachers working collaboratively toward shared goals.

What are the benefits of a distributed leadership model in schools? Silns and Mulford (2002) have shown in their study that student achievement is more likely to improve in schools where leadership is distributed throughout the school. Teachers in these schools are active participants in professional learning communities that have as their goal the improved learning and achievement of students. DuFour (2004) states:

Professional learning communities judge their effectiveness on the basis of results…Every teacher team participates in an ongoing process of identifying the current level of student achievement, establishing a goal to improve the current level, working together to achieve that goal, and providing periodic evidence of progress (p.10).
Senge (1990) wrote, “A shared vision is a vision that many people are truly committed to because it reflects their own personal values” (p. 206). When teachers dialogue about their values and work together collaboratively to improve teaching and learning, the results are improved student achievement (Spillane et al, 2004; Silns & Mulford, 2002; Fullan, 2001; Perkins, 1992; Marzano, 2003).

Because of the importance of fostering teacher leadership in developing and sustaining professional learning communities within schools, it is important to know what teacher activities promote the development of teacher leadership. Little (1995) suggests that teacher leadership develops through mentoring relationships, coaching and peer observations, and shared planning in response to data.

Similarly, Darling-Hammond (1990) says that teacher leadership develops through collaboration with other teachers and classroom research on new teaching approaches, the results of which are shared with colleagues.

Katzenmeyer and Moller (2001) describe several characteristics of school cultures that support teacher leadership:

- Teacher leadership is coached and developed through opportunities to lead and mentor.
- Teachers are given the autonomy needed to implement new programs.
- Collegiality among teachers is the norm of the community.
- Teachers are supported in a positive environment and are recognized for their achievements and contributions.
• Teachers participate in decisions regarding important matters of the school.

The report of the Task Force on Teacher Leadership (2001) strongly recommends that teacher leadership should be fostered in schools, which will result in a more professional atmosphere in schools, which in turn, will promote an environment of continuous improvement that is essential for meeting the increasingly complex learning challenges facing students today. Schools where teachers are valued as experts and where they are involved in substantial roles in decision-making and planning are better prepared to attract and retain quality teachers.

Barth (2001) suggests that students and society ultimately benefit from teachers assuming leadership roles because schools become more democratic places for everyone. Students’ understanding of their roles and responsibilities in a democracy is learned as much, if not more, from their observations and experience as their coursework in social studies. Starratt (2003) writes, “preparation for citizenship is still one of the mainstream, traditional purposes of public education” (p. 90).

Barth (2001) also states that studies on school governance suggest that schools where students are academically successful and have fewer discipline problems are schools where there is more teacher participation in leadership roles, suggesting, at least, a positive correlational relationship between teacher leadership and student success.

Elmore (2000) states that the success of students is contingent upon breaking down the “privacy of practice” in schools and developing a culture of collegiality, which requires, by necessity, that teachers assume roles of leadership. He says:
Distributed leadership posits a model in which instructional practice is a collective good – a common concern of the whole institution – as well as a private and individual concern. It posits a theory of leadership that, while respecting, acknowledging, and capitalizing on differences in expertise, predicts failure in the social isolation of practice and predicts success in the creation of interdependencies that stretch over these differences (p. 24).

Crowther et al. (2002) argue that “teacher leadership appears to be inseparable from successful school reform as it is currently envisioned”, and that their research “offers strong evidence that school-based interventions, involving teacher leadership… can produce enhanced educational outcomes” (p. xix).

While the focus of this study is the effect of the Math Mentor Program on the performance and confidence of new teachers, a related and potentially significant outcome of the program is the opportunity it creates for teacher leadership both for the mentor and mentee. One of Elmore’s (2000) principles of distributed leadership is that learning requires modeling and that the purpose of leadership is the improvement of instructional practice. He further maintains that “leadership roles flow from the expertise required for learning and improvement” (pp. 20-21).
IV. Summary

The literature is fairly conclusive regarding the strong link between teacher self-efficacy and student performance. Additionally, a strong relationship exists between a teacher’s content knowledge of mathematics and pedagogical skills and student performance.

School districts that offer comprehensive induction programs are better able to retain highly qualified teachers better than districts that offer little mentoring support. Effective induction programs model best practices in adult learning.

Student achievement correlates positively with schools that promote and support professional learning communities and teacher leadership.

Overall, what can be learned from the literature on self-efficacy, induction programs, adult learning, and content-based professional development is that in designing an induction program for new teachers in a particular discipline it is important that the participants improve their own sense of self-efficacy and knowledge of the discipline through learning activities that are centered in the classroom.

In Chapter 3, the design of the study of the Math Mentor Program will be described.
Chapter III

Design of the Study

I. Introduction

“The Impact of a Math Mentoring Program to Prepare New Elementary Teachers to Teach Mathematics” is an evaluative, descriptive case study (Merriam, 1998, Gay et al., 2006), which focuses on the effects of a Math Mentor Program on the content knowledge, confidence, and instructional practice of new elementary teachers. In this chapter, the rationale for using a qualitative case study as the design model for the study is discussed. The chapter then describes the research questions, research methodology, and sample. Chapter 3 also provides a rationale for the sample, a description of the pilot test, the data gathering procedures, methods of data analysis, formats and frameworks for reporting the data, as well as, limitations of the study.

II. Design of the Study

A qualitative case study is the best model to study the effect of the Math Mentor Program as it relates to content knowledge, confidence, and instructional practice of new elementary teachers. The group of “new” teachers included those teachers who were new-to-teaching or new-to-their-grade level during the year of the study. “A qualitative case study is an intensive, holistic, description and analysis of a single instance, phenomenon, or social unit” (Merriam, 1988, p.21). In this study, the Math Mentor
Program is described through the experience of the participants for the purpose of evaluating the effectiveness of the program in achieving its goals.

Merriam (1998) contends that a “case study is a particularly suitable design if you are interested in process” (p. 33). Reichardt and Cook (as cited in Merriam, 1998) say that one meaning for ‘process’ “is causal explanation: discovering or confirming the process by which the treatment had the effect that it did” (p. 33). Merriam (1998) goes onto say, “Questions about process (why or how something happens) commonly guide research, as do questions of understanding (what happened, what does it mean to those involved)” (p.59).

This case study is a particular type of qualitative research, called an evaluative, descriptive case study. It is a descriptive case study because the source of data for this study will be questionnaires, interviews, journals, and observations. Gay et al. (2006) describes descriptive research as “survey research, (which) determines and describes the way things are…descriptive data are usually collected by questionnaire surveys, telephone surveys, interviews, or observation” (p. 159).

This study is also an evaluative case study because “evaluative research is the systematic process of collecting and analyzing data about the quality, effectiveness, merit, or value of programs, products, or practices” (Gay et al., 2006, p. 7).

Evaluative case studies, according to Merriam (1998) “involve description, explanation, and judgment.” Kenny and Grotelueschen (as cited in Merriam, 1998) offer several reasons for choosing a case study design when doing an evaluation:
Case study can be an important approach when the future of a program is contingent upon an evaluation being performed and there are no reasonable indicators of programmatic success which can be formulated in terms of behavioral objectives of individual differences…or to develop a better understanding of the dynamics of the program (p.39).

This case study seeks to extend the knowledge base of what constitutes an effective content-based induction program for new teachers. The researcher who developed the Math Mentor Program and who is the Assistant Superintendent for Curriculum and Instruction also seeks to evaluate the effectiveness of the program from the point of view of cost/benefit when deciding where to allocate professional development funds.

III. Research Questions and Hypotheses

The research questions that will guide this study are the following:

1. How did the Math Mentoring Program affect participating teachers’ perceptions of their ability to teach the mathematics curriculum, *Investigations Into Number, Data and Space*?
   f) What math content did they learn?
   g) What math pedagogy did they learn?
   h) What effect did the program have on their confidence to teach mathematics?
   i) How was student achievement affected?
   j) What classroom practices were instituted or changed as a result of their participation?
2. How did the various components of the Math Mentoring Program contribute to new teachers’ perception of their improved content knowledge, pedagogical strategies, confidence, and classroom practices?

e) What was the effect of observing a mathematics lesson taught by the mentor?

f) What was the effect of group discussions with the cohort group and mentor?

g) What was the effect of keeping a reflective journal?

h) What was the effect of reading articles focused on math pedagogy?

**Research Hypotheses**
(correspond to research questions)

**Research Question 1:**

1a) Teachers will report that their knowledge of mathematics broadened and deepened as a result of their participation in the Math Mentor Program.

1b) Teachers will report that their knowledge of math pedagogy expanded as a result of their participation in the Math Mentor Program.

1c) Teachers will report that they felt supported and their confidence for teaching mathematics improved as a result of their participation in the Math Mentor Program.

1d) Students taught by new teachers will have scores on the end-of-year assessment within one standard deviation of the mean of the scores of students taught by veteran teachers (those with at least two years of experience teaching the mathematics curriculum).

1e) Teachers will be able to cite at least three classroom practices that were instituted or changed as a result of their participation in the Math Mentoring Program.
Research Question 2:

2a) Teachers will report that observing a math lesson taught by their mentor was the most valuable component of the Math Mentoring Program.

2b) Teachers will report that the pre and post observation discussion were valuable.

2c) Teachers will report that keeping a journal was helpful, but not as helpful as the observations and discussions.

2d) Teachers will report that some articles were more helpful than others, but that this was the least helpful of the four activities.

IV. Research Methodology

The research methods used to build this case study included questionnaires, interviews, journals, observations, and end-of-year mathematics assessment scores. The questionnaire asked the participants (teachers) to self-report their feelings, observations and experiences. All participants were asked the same questions on the questionnaire, which had both open-ended and close-ended questions answered using a Likert scale. The advantage of the questionnaire was that all of the participants in the study could respond to the same standardized questions for comparative analysis.

While personal interviews “allow rich, more complete responses (than questionnaires), they have the least standardization and take the longest to administer” (Gay et al., 2006, p.165) than questionnaires.

“In observation, qualitative researchers obtain data by simply watching the participants. The emphasis during observations is on understanding the natural
environment as lived by participants, without altering or manipulating it” (Gay et al., 2006, p. 413). Conducting observations can be an effective research tool to understand the correspondence between self-reported behaviors and exhibited behaviors.

Another source of data was teacher journals. Journals provided the researcher with a window into the experience of individual teachers during and after mentor sessions. Teachers observed their mentor teacher teach a mathematics lesson once a month, which was followed by a discussion of the lesson with her cohorts and mentor. Teachers recorded in their journals what mathematics and pedagogical insights they learned in response to prompting questions.

The data gathered from three sources (questionnaires, interviews, and journals) was analyzed through the themes expressed in the sub-questions of each research question. Data from researcher observations of mentor meetings was used to corroborate the data from the other three sources.

An additional source of data was a quantitative analysis of assessment results. The scores of the new teachers’ students on the end-of-year mathematics assessment were compared to the student scores of veteran teachers (those with at least two years of experience teaching the mathematics curriculum) at the same grade level. The purpose for comparing these scores was to determine if a gap in student performance existed between veteran and new teachers after new teachers had participated in the mentoring program for one year.
V. Sample and Rationale for the Sample

A mandatory component of the district’s induction program was that all new and new-to-their-grade teachers participate in the Math Mentor Program. Teachers in the program spent a morning or afternoon (2.5 hrs.) in their mentor’s classroom approximately once per month for six months. They observed their mentor teach a mathematics lesson from TERC’s *Investigation into Number, Data and Space*. The observation was preceded and followed by a discussion of the lesson and the mathematics content of the lesson.

During the four years preceding the study, the school district had experienced significant turnover of its elementary staff - nearly two-thirds of the elementary teachers were new to the district. Most of these teachers at the time of hire were either new to teaching or had only a few years of teaching experience.

The school district is a fairly high achieving district as measured by the annual state assessment (MCAS) scores. Very few elementary students score in the warning category for either mathematics or ELA. The mathematics proficiency rate for all students in grades 3, 4, and 5 averages 81% (multiple year average). The socio-economic profile of the community has been changing over the past decade due in part to its proximity to a major city and rising median income. In 2000, the median family income was $64,344. In 2007, it was $78,744. Fifty-three percent of the residents over age 25 hold a college degree or an advanced college degree, as compared to 30% nationally. The School Committee and the community have a strong expectation that MCAS scores will improve each year.
In the year of the study, eleven elementary teachers were hired and four in-district teachers were transferred to a new grade. As compared to previous years, eleven new elementary teachers was a relatively low number of new hires. Two years earlier, the district hired 34 new elementary teachers.

The sample for this study was the set of six elementary teachers who were new-to-the-district and who met other criteria. Invitation letters to participate in the study were sent to all 15 teachers. While all 15 teachers agreed to participate, the researcher chose the six teachers in the study based on several factors: (1) their past experience teaching the district’s mathematics curriculum, (2) their previous elementary teaching experience in another school or district, and (3) whether there were other new teachers at their grade level. None of the six teachers who were chosen for the study had taught mathematics using TERC’s *Investigation Into Number, Data and Space*. Two of the six teachers had no previous teaching experience and all had cohorts at the same grade level who also participated in the Math Mentor Program. The teachers were guaranteed privacy and assurance that their participation in the study would have no affect on their evaluation.

VI. Pilot Test

The questions asked in the interviews were based on the research questions. The interview questions were reviewed with a small group of mentor teachers and an expert group of educators made up of elementary mathematics specialists, teachers, and principals who were not participants in the Math Mentor Program.
The interview questions were piloted with one teacher in the Math Mentor Program whose responses were not included in the study. Modifications to the questions were made after the trial interview. The slightly modified questions were used for all six interviews.

VII. Data Gathering Procedures

Data was obtained from a variety of sources:

- Interviews with teachers
- Teacher reflective journals
- Researcher notes from personal journal and mentor session observations
- Initial survey questionnaire
- End-of-year survey questionnaire
- Student scores on end-of-year common grade-level assessments

Data was collected with consideration for reliability, validity, and evidence of researcher bias. The researcher of the project designed the Math Mentor Program, selected the mentor teachers, and developed the data-gathering instruments (with input from mentor teachers and expert collaborators). To minimize the effect of research bias, data displays were subjected to the scrutiny of an objective expert group, who were not participants in the program. The study’s validity is enhanced by the triangulation in data collection (Miles & Huberman, 1994, p.267).

Interviews were conducted with the chosen sample of six teachers who participated in the Math Mentor Program in the year of the study. Merriam (1998) states, “Interviewing is necessary when we cannot observe behavior, feelings, or how
people interpret the world around them. It is also necessary to interview when we are interested in past events that are impossible to replicate” (p.72). Interviews were conducted at the end of the school year so that teachers would have the opportunity to reflect on their whole experience rather than just part of it.

The interviews provided a rich source of data to understand the effect of the program on teacher gains in mathematical knowledge, changes in instructional practice, and confidence in teaching mathematics. All of the interviews were taped and later transcribed for easier referral.

During the year of the study, all teachers were asked to keep a reflective journal in which they responded to guiding questions after each mentor-observation session. Teachers’ journals provided insight into their reactions to specific lessons observed and how they transferred the concepts and instructional strategies into their own classroom.

The guiding questions helped focus teachers’ observations while the mentor was teaching, as well as, frame the post-observation discussions. The researcher with input from the mentor teachers developed the questions. The focus questions highlighted what this group of veteran teachers felt were important goals and outcomes for any well-taught mathematics lesson.

While the offer was given to teachers to write their reflections in their journal at the end of each observation/discussion session, teachers generally chose to use the time to further discuss observations and insights with their peers and mentor. They were asked to send their mentor a copy of their reflections within a week of the observation for the mentor to send back comments. Teachers submitted completed journals to the
researcher at the end of the year. However, the researcher read journal installments
given to her by the mentors throughout the year to follow the progress of the teachers.

Notes taken by the researcher during mentor observation sessions helped to remind
her of the mathematics content and pedagogy of particular lessons when reading
journals and interview transcripts later in the study. Journal notes taken by the
researcher provided a history of the issues that affected the implementation of the Math
Mentor Program during the year of the study.

At the beginning of the school year, teachers were asked to complete an initial
questionnaire, which asked the teacher about her preparation for teaching mathematics
and her feelings about teaching mathematics. The questionnaire contained both open-
ended and close-ended questions. From this data, the researcher hoped to establish a
baseline to gauge the effect of the Math Mentor Program on teacher confidence, gains
in mathematical knowledge, and pedagogical strategies.

The end-of-the-year questionnaire included some of the same questions as the
initial survey. The end-of-year questionnaire provided the researcher with data
regarding teachers’ perceptions of their gains in mathematics knowledge, confidence in
teaching mathematics, and expanded instructional methodologies.

In June, students in all of the elementary grades were assessed with a common
end-of-the-year, grade-level test. The scores for each student were inputted into the
district’s data bank. The student scores of new teachers were compared to the student
scores of veteran teachers. Veteran teachers for this study were defined as those
teachers who had two or more years experience teaching the district’s mathematics curriculum.

Triangulations of data from interviews, questionnaires, and journals enabled the researcher to provide the descriptions and analysis that characterize qualitative research. “…Triangulation is a way to get to the finding in the first place – by seeing or hearing multiple instances of it from different sources by using different methods and by squaring the findings with others it needs to squared with.” (Miles & Huberman, 1994, p.267)

The data was collected according to the following schedule in Table 1.

Table 1 – Data Collection Schedule

<table>
<thead>
<tr>
<th>Month</th>
<th>Teacher Initial Survey</th>
<th>Teacher Interview</th>
<th>Teacher Journal</th>
<th>Teacher End-of-Year Survey</th>
<th>Researcher Notes and Journal</th>
<th>Common Final Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>August</td>
<td></td>
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<td></td>
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<tr>
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<td>X</td>
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<td>X</td>
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<tr>
<td>November</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>December</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>January</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>February</td>
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<td>X</td>
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<td>X</td>
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<td>May</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>June</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>July</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
VIII. Method of Data Analysis

Data from the following sources was collected, coded, and analyzed:

Instrument 1 - Teacher initial survey questionnaire
Instrument 2 - Teacher interviews
Instrument 3 - Teacher journal entries
Instrument 4 - Teacher end-of-year survey questionnaire
Instrument 5 - Researcher notes and journal
Instrument 6 - End-of-year common assessments

A hired secretary transcribed all interviews. Teacher responses from interview transcripts, journals, open-ended survey questions were coded using the same thematic codes listed below, which relate to the research questions. The codes that were used:

1M  Research Question #1A (Math Content Learned)
1P  Research Question #1B (Math Pedagogy)
1C  Research Question #1C (Confidence)
1SA Research Question #1D (Student Achievement)
1CP Research Question #1E (Classroom Practice)
2O  Research Question #2A (Effect of Observing Math Lesson)
2D  Research Question #2B (Effect of Group Discussions)
2J  Research Question #2C (Effect of Keeping Reflective Journal)
2R  Research Question #2D (Effect of Reading Math Articles)

Pattern counts were used to track the frequency of responses in order to report trends and emphasis.
Researcher notes from observations and leadership journal entries were coded in the same way teacher responses were coded.

Closed-end responses for both the initial and end-of-year survey questionnaires were tallied.

Student scores on the end-of-year assessments reflected the percent of questions correct on the assessment. An overall student average was calculated for each teacher in grades 1-5. The mean, median, and range were calculated for the whole grade as well as for veteran teachers in each grade. The student scores of other teachers in the Math Mentor Program who were not in the study were removed from the sample to calculate the mean and standard deviation for veteran teachers. The student averages of teachers in the study were compared to the student averages of veteran teachers in their grade.

By triangulating the data from different sources (surveys, interviews, journals, observations, and assessments), the researcher looked for patterns and relationships that would provide answers to the research questions.

IX. Formats for Reporting the Data

A combination of text and tables were be used to report the data. The nine tables that were used to display data are as follows:
Table 1 – Math Mentor Program Participants Experience and Assignment

In this table, data regarding teachers’ grade level assignment, prior years of teaching experience, and prior years of experience teaching the mathematics curriculum are displayed.

Table 2 – Case Study Participants Biographical/Experience Background

In this table the grade assignment, highest degree obtained, number of math courses beyond high school, math methods course experience (Y/N?), prior years of teaching experience, and prior years of teaching TERC’s Investigation Into Number, Data and Space, are displayed for the six teachers in the study.

Table 3 – Initial Survey

In this table the grade-level, self-reported September and January confidence scores, and the change are reported for all six teachers in the study.

Table 4 – Responses to Open-Ended Questions - Initial

In this table the responses of the six teachers in the study to the open-response question on the initial questionnaire are reported.

Table 5 – Response of Teachers

In this table the responses as totals are reported for each statement on the end-of-year questionnaire for five teachers in the study. One teacher did not complete the
questionnaire. Teachers chose one of four responses – strongly agree, somewhat agree, somewhat disagree, strongly disagree – to nine statements.

Table 6 – Confidence Numbers from September to June

In this table the self-reported confidence numbers from the September initial questionnaire and the June end-of-year questionnaire along with the change in numbers are displayed for the five teachers who had returned both questionnaires to the researcher.

Table 7 – Comparison of Assessment Means of MMP Study Teachers to Grade 1 Cohort

(No MMP Teachers)

In this table the class (all students in the class) assessment mean for the three first grade teachers in the study are compared to the grade 1 assessment mean for all veteran first grade teachers along with a positive or negative delta number reflecting the difference.

Table 8 Comparison of Assessment Means of MMP Study Teachers to Grade 4 Cohort

(No MMP teachers)

In this table the class (all students in the class) assessment mean for the fourth grade teacher in the study is compared to the grade 4 assessment mean for all veteran fourth grade teachers along with a positive or negative delta number reflecting the difference. The table also displays the assessment class means for the other MMP fourth grade teachers who were participants in the MMP but who were not in the study. Their
deltas numbers as compared to the veteran teachers’ student mean score are displayed as well.

Table 9 – Comparison of Assessment Means of MMP Study Teachers to Grade 5 Cohort (No MMP Teachers)

In this table the class (all students in the class) assessment mean for the fifth grade teachers in the study are compared to the grade 5 assessment mean for all veteran fifth grade teachers along with a positive or negative delta number reflecting the difference. The table also displays the assessment class means for the other MMP fifth grade teachers who were participants in the MMP but who were not in the study. Their deltas numbers as compared to the veteran teachers’ student mean score are displayed as well.

X. Framework for Discussing the Findings

The findings will be discussed in reference to the study’s two research questions:

• How did the Math Mentoring Program affect participating teachers’ perception of their ability to teach the mathematics curriculum?
  ✤ What math content did they learn?
  ✤ What math pedagogy did they learn?
  ✤ What effect did the program have on their confidence to teach mathematics?
  ✤ How was student achievement affected?
What classroom practices were instituted or changed as a result of their participation?

- How did the various components (observations, group discussions, reflective journal, and math articles) of the Math Mentoring Program contribute to new teachers’ perception of their improved content knowledge, pedagogical strategies, confidence, and classroom practices?

Research indicates that the performance of teachers is closely related to their sense of teaching efficacy (“teacher’s judgments about their ability to promote student learning” (Hoy & Spero, 2005, p343)). Teacher efficacy was identified thirty years ago in a study by the RAND Corporation as “one of the few teacher characteristics related to student achievement (Armor et al., 1976).

Bandura (1977) proposed a theory of self-efficacy, which is developed through four types of experiences, the most powerful being mastery experiences. A mastery experience comes from knowing a subject thoroughly, which relates to subject content knowledge.

A second source for the development of self-efficacy is vicarious experiences. “Vicarious experiences are those in which someone else models a skill. The more closely the observer identifies with the model, the stronger will be the impact on efficacy” (Hoy & Spero, 2005). The primary intervention is this first year induction program for new teachers is the monthly observation of mentor teachers teaching a mathematics lesson. These observations correspond to Bandura’s definition of vicarious experiences.
The research work of Bandura and others suggest that a teacher’s sense of efficacy can be affected more in her earlier years of teaching than later. Bandura (1997) found that the level of support a teacher had in her first year of teaching correlated positively with self-efficacy (Hoy & Spero, 2005). The Math Mentor Program is a program designed for first year teachers who are either new to teaching or to a particular grade level.

This study examined whether teachers participating in the Math Mentor Program perceived an improvement in their mathematics content knowledge, mathematics pedagogy, and confidence teaching mathematics, which should correspond to an improved sense of self-efficacy as a mathematics teacher.

Data from student performance on the end-of-year assessment also was an indicator of the success of the Math Mentor Program in preparing the teachers in the study to successfully teach the mathematics curriculum.

XI. Limitations of the Study

Given that the researcher is the person who designed the Math Mentor Program, selected the mentors, and designed most of the data gathering instruments, there may be some bias in the analysis of the results to align positively with the researcher’s hopes and expectations for the success of the program. In order to mitigate bias, the researcher had a colleague check the data analysis and interpretation. Triangulation of data also served to mitigate bias.
The previous teaching or educational experiences of the new teachers could have been a significant factor in their perceived gain in mathematics content knowledge and pedagogical competency. Since most learning is an associative process, teachers’ educational and/or experiential background could have influenced what they learned through participation in the Math Mentor Program. Teachers with a moderate to strong background in mathematics or prior teaching experience might not have been affected the same way by a mentor observation session as someone with a limited background in mathematics or no prior teaching experience.

The variability of each new teacher’s school environment could also have been a significant factor in influencing their confidence and performance. Some of the elementary schools had a stronger “mathematics culture” than other schools. For example, in the year of the study three of the elementary schools agreed to meet jointly at least three times during the year by grade level to work on a mathematics vocabulary project. Some schools dedicated more of their building meetings to work on mathematics-focused activities than other schools.

Another limiting factor that would have represented a threat to internal validity was whether a new teacher was enrolled in a graduate course in mathematics or a mathematics methods course as part of a master’s degree program. None of the six teachers in the study were enrolled in graduate courses.

Chapter 4 will provide an analysis of the data and findings from this research study.
CHAPTER IV
Research Findings

I. Introduction

In this chapter the findings of the study will be presented. The chapter is organized to present an overview of the case and the findings that emerged from the data collected using four instruments: journals, interviews, questionnaires, and assessments. The research questions will be addressed through the framework of the themes outlined in the research sub-questions. The instrument sections will be organized by research question and the themes associated with that question. The findings on student achievement (sub-question four of research question one) will be discussed separately in section 6. The major findings from all the instruments are then summarized in section 7. The chapter contains the following sections:

1. Introduction:
   - An overview of the chapter

2. Description of the Case:
   - Information to provide a context for the case study in the following categories:
     - Setting
     - Description of the Math Mentor Program
     - Participant information

3. Journals:
- Findings from journal responses, which were written after each mentor session, organized around the themes of each research question:

**Research Question 1** - How did the Math Mentoring Program affect participating teachers’ perception of their ability to teach the mathematics curriculum, *Investigations Into Number, Data and Space*?

- Math content learned
- Math pedagogy learned
- Confidence
- Classroom practice

**Research Question 2** - How did the various components of the Math Mentoring Program contribute to new teachers’ perception of their improved content knowledge, pedagogical strategies, confidence, and classroom practices?

- Observation of mentor
- Group discussions
- Journal
- Math Articles

4. Interviews:

- Findings from interviews conducted at the end of the school year, organized around the following themes in each research question:

**Research Question 1** - How did the Math Mentoring Program affect participating teachers’ perception of their ability to teach the mathematics curriculum, *Investigations Into Number, Data and Space*?
• Math content learned
• Math pedagogy learned
• Confidence
• Classroom practice

**Research Question 2** - How did the various components of the Math Mentoring Program contribute to new teachers’ perception of their improved content knowledge, pedagogical strategies, confidence, and classroom practices?

• Observation of mentor
• Group discussions
• Journal
• Math Articles

5. Questionnaires:
   - Findings from questionnaire data collected from participants in the fall/winter and at the end of the school year.

6. End-of-year mathematics grade-level assessments:
   - Findings regarding student achievement from the results of the common end-of-year, grade-level mathematics assessments for participants in the case study and the entire MMP cohort as compared to the aggregate mean score of students of veteran teachers at each grade.

7. Other Significant Findings

8. Summary of findings:
   - A synopsis of the major findings as they relate to the research questions.
9. Conclusion

The goal of Chapter IV is to provide a rich description of the case and its participants’ thoughts and feelings on their experience in the Math Mentor Program, which was offered to them as a support for teaching mathematics for the first time at their grade level using *Investigations Into Number, Data and Space*. This data will inform the discussion of findings in Chapter V.

II. Description of the Case

This study is a qualitative, descriptive case study of six teachers’ experience in the Math Mentor Program during their first year of teaching mathematics at their grade level in a suburban Massachusetts elementary school using *Investigations Into Number, Data and Space* as the primary resource for the mathematics curriculum. In order to understand the study, it is necessary to provide some contextual information on the suburban community, the participants, and the constructivist nature of the mathematics curriculum. The names of places and participants have been changed in order to maintain confidentiality.

*Setting*

The study takes place in a suburban Massachusetts community known for the quality of its schools. The academic success of the schools as measured by the students’
performance on the state’s annual proficiency assessment (MCAS) ranks the district’s elementary schools overall among the top 20% of all elementary schools in the state. The elementary schools vary in their performance in mathematics. The gap in performance has steadily narrowed over the last ten years due to a common mathematics curriculum, common unit and end-of-year assessments, and professional development.

The elementary schools vary in size from approximately 280 students to 420 students. The smaller schools have only two classes at each grade level while the larger schools may have three or four classes at a grade level. The student population during the study was 79.4% White, 9.5% Asian, 3.6% African-American, and 4.6% Hispanic. Socio-economically, the student population is diverse, though not all schools reflect the same diversity. The range of housing includes large and small single-family homes, two-family homes, medium-size apartment buildings, and low-income housing, though the population is skewed toward middle class; 12% of the students participated in the subsidized lunch program.

The school district is a fairly high achieving district as measured by the Massachusetts Comprehensive Assessment System (MCAS) scores. Very few elementary students score in the warning category for either mathematics or ELA. The mathematics proficiency rate for all students in grades 3, 4, and 5 averages 81%.

The socio-economic profile of the community has been changing over the past decade due in part to its proximity to Boston and rising median income. In 2000, the median family income was $64,344. In 2007, it is $78,744. 53% of the residents over
age 25 hold a college degree or an advanced college degree, as compared to 30% nationally.

The elementary schools, as well as secondary schools, enjoy broad community and parental support. An education foundation raises money for both small teacher grants and large curriculum initiatives. The community has high expectations for and pride in the performance of its children on statewide and national exams, in athletics, and the performing arts.

Over the last five years, the elementary schools have experienced a large turnover in teaching staff. A major factor in this turnover has been the retirement of veteran teachers. Nearly two-thirds of the elementary teachers were hired new to the district in the four years prior to the study. When hiring new elementary teachers, the district has a preference for hiring teachers with some prior teaching experience if possible, though not necessarily teachers who have previously taught mathematics using TERC’s *Investigation Into Number, Data and Space* curriculum.

**Description of the Math Mentor Program**

The Math Mentor Program is a job-embedded professional development program for new elementary teachers in grades K-5 who are new to the district or who are transferring grade levels. New teachers at each grade level are assigned a math mentor who is an experienced teacher chosen because of her demonstrated skill in teaching the mathematics curriculum.
Teachers in the Math Mentor Program during the year of the study met with their math mentor in August for one day prior to the start of the school year to review the grade-level goals of the mathematics curriculum, the common assessments (6-8 assessments for each grade) and the curriculum pacing chart. New teachers worked with their mentor to plan September’s lessons. The teachers and their mentor met six additional times during the year for two and half hours in the mentor’s classroom to observe the mentor teach a mathematics lesson and to discuss the lesson and any other difficulties the new teachers were experiencing with the curriculum. During the school year, the mentor was available to answer any questions the new teacher may have had with regard to teaching the mathematics curriculum.

Teachers were required to keep a journal of their reflections after each observation. They were provided with a list of guiding questions to frame their reflections about the observation. Their journals were sent to the mentor between sessions for comment and possible discussion. Reflections were also shared with the other members of the cohort (same grade-level mentees, if any) during group discussions at subsequent meetings.

Throughout the year, mentors shared with their mentees articles regarding the practice of teaching mathematics in elementary classrooms.
Participant Information

During the year of the study, there were fifteen new elementary teachers; eleven who were new to the district and four who transferred grade levels. All but two of the eleven who were new to the district had had some previous teaching experience either in a public or private school. Table 1 below displays an overview of the teaching experience of all fifteen participants in the Math Mentor Program. All fifteen teachers are females.

Table 1  Math Mentor Program Participants Experience and Assignment

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Assignment</th>
<th>Prior Teaching Experience (Yrs.)</th>
<th>Prior Experience Teaching TERC (Yrs./Grade)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Grade 5</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>B</td>
<td>Grade 5</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>Jane</td>
<td>Grade 5</td>
<td>1.5</td>
<td>0</td>
</tr>
<tr>
<td>C</td>
<td>Grade 5</td>
<td>2</td>
<td>1 - Grade 3</td>
</tr>
<tr>
<td>Carolyn</td>
<td>Grade 5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>D</td>
<td>Grade 4</td>
<td>4</td>
<td>4 - Grade 3</td>
</tr>
<tr>
<td>Barbara</td>
<td>Grade 4</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>E</td>
<td>Grade 4</td>
<td>2</td>
<td>1 - Grade 5</td>
</tr>
<tr>
<td>F</td>
<td>Grade 3</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>G</td>
<td>Grade 2</td>
<td>5</td>
<td>1 - Grade 3</td>
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<tr>
<td>H</td>
<td>Grade 2</td>
<td>3</td>
<td>2 – Kindergarten</td>
</tr>
<tr>
<td>Susan</td>
<td>Grade 1</td>
<td>2</td>
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</tr>
<tr>
<td>Mary</td>
<td>Grade 1</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>I</td>
<td>Grade 1</td>
<td>16</td>
<td>6 – Grade K &amp; 1</td>
</tr>
<tr>
<td>Sharon</td>
<td>Grade 1</td>
<td>0</td>
<td>0 (student teaching exp.)</td>
</tr>
</tbody>
</table>

* Fictitious names rather than a letter identify teachers in case study.

The case study focused on only six of the participants, even though all fifteen participants volunteered to be in the study. The participants were selected based upon their prior teaching experience and their prior experience teaching mathematics using
TERC’s *Investigation Into Data, Number and Space*. Those teachers with the fewest years of experience in both categories were selected with priority given to “0” years of experience teaching the mathematics curriculum. While it would have been desirable to have all grade levels represented in the case study, the experience criteria were deemed more important by the researcher in selecting case study participants. The new teacher in third grade who had no prior experience with the district’s mathematics curriculum was not chosen because the teacher did not have a grade-level cohort, so would not be able to comment on the effect of group discussions on her practice. The two teachers in second grade were not chosen due to the fact that both had relatively significant prior teaching experience and experience teaching mathematics using the TERC program at a different grade level.

**Teachers in the Case Study**

The teachers selected for the case study had no previous experience teaching mathematics using TERC’s *Investigation into Data, Number, and Space* as the primary resource prior to teaching in the district with the exception of one teacher in first grade who was familiar with the program through her student teaching experience. Table 2 displays information regarding the participants’ age, level of education, mathematics courses taken beyond high school, teaching experience, and whether they had ever taken a mathematics method course.
Table 2  Case Study Participants Biographical/Experience Information

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Grade Assign.</th>
<th>Highest Degree</th>
<th>Math Courses (#Beyond H.S.)</th>
<th>Math Method Course (Y/N)</th>
<th>Teaching Exp. (Yrs.)</th>
<th>TERC Exp. (Yrs.)</th>
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<tr>
<td>Jane</td>
<td>5</td>
<td>Ed.M.</td>
<td>1</td>
<td>Y</td>
<td>1.5</td>
<td>0</td>
</tr>
<tr>
<td>Carolyn</td>
<td>5</td>
<td>Ed.M.</td>
<td>6</td>
<td>Y</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Barbara</td>
<td>4</td>
<td>B.A.</td>
<td>2</td>
<td>Y</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Sandra</td>
<td>1</td>
<td>Ed.M.</td>
<td>3</td>
<td>N</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Mary</td>
<td>1</td>
<td>B.A.</td>
<td>2</td>
<td>N</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
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III. Journals

Teachers in the Math Mentor Program were required to keep a journal as a tool for reflection about their experience in the program. Guiding questions were given to teachers to focus their observations while observing in their mentor’s classroom. The mentors and researcher developed the guiding questions. The questions relate to the research questions of this study, but do not paraphrase the research questions. The questions were:

1. What did you learn about questioning? What questions enrich the mathematical discourse?
2. What did you learn about mathematical connections? Making connections with past knowledge?

3. When in the lesson were students asked to reason mathematically?

4. Describe rich mathematical conversations heard among or between students.

5. Describe how you incorporated ideas learned into your classroom.

The responses of the six teachers in the study will be relayed through the lens of the themes embedded in the two research questions.

**Research Question 1 - How did the Math Mentoring Program affect participating teachers’ perception of their ability to teach the mathematics curriculum, *Investigations Into Number, Data and Space*?**

**Math Content Learned**

The journal questions focused primarily on pedagogy and classroom practice. What teachers learned about mathematics related more to their new understandings about alternate ways to present an already known concept than to learning a new concept for the first time. Intermediate and primary grade teachers varied in degree on this issue. Fifth and fourth grade teachers acknowledged more in their writings about deepening understandings of certain mathematical concepts, while first grade teachers only focused on alternate approaches to teaching a particular mathematics concept.

Carolyn (grade 5) wrote about learning the value of using visual representations to represent mathematical relationships:
Over the last few weeks, Heather’s [mentor] students have been working through the “Name That Portion” section of TERC. They are now very familiar with fractions, and seem to have a solid grasp of the concepts taught in this investigation. In this lesson, Heather introduced four fraction word problems to her students. However, in order to solve these problems, students had to use visual representations as opposed to calculations. Heather knew that most of her students would be able to solve these problems using the LCM [Least Common Multiple] or some other method, but she wanted to make sure that her students could represent these problems using visual models. In this way, students were asked to solve problems in a way that they weren’t necessarily comfortable or familiar with. I thought that this was a wonderful idea, and it is something that I would not have thought about doing in my own classroom. I like that she is asking her students to “think outside the box” and try to solve problems in ways that they wouldn’t have originally….

After my visit to Heather’s classroom this month, I decided that I needed to try out the same exact lesson in my own classroom. I wanted to see if my students would be able to visually represent fractions, like Heather’s class. Although my students were able to do this, it was clearly a struggle, and many of my students didn’t understand why I was making them “show” their work as opposed to calculating it. This really drove home the fact that I need to be exposing my students to multiple ways of solving mathematical problems.
Mary (grade 1) wrote about being introduced to the abacus as a tool to explore number combinations, “Linda [mentor] had been building her class’ understanding of number combinations for some time and introduced a simple abacus for continued exploration of the ‘big idea’”. Mary indicated that she planned to introduce the abacus to her students because it was a great visual tool for addition.

**Math Pedagogy Learned**

The guiding questions primarily focused teachers’ reflective writing on pedagogical issues. The four universally mentioned areas of improved knowledge and implementation were: questioning, making connections with prior knowledge and other subjects, differentiating instruction, and building mathematics vocabulary. Several of the teachers mentioned the pedagogical value of students discussing their thinking with each other in pairs or small groups. One teacher mentioned the value in understanding how to structure the hour of mathematics instruction.

Every teacher wrote extensively about “questioning” as a skill that they came to appreciate and to improve upon with their own students. They felt that their ability to ask questions that probe and deepen their students’ understanding improved through observing their mentor – and each other in the case of the first grade teachers.
**Questioning:**

Carolyn (grade 5) wrote about what she learned about “questioning” from her mentor:

From observing Heather [mentor], I was able to learn a great deal about questioning and how questions can enrich our mathematical discourse. Whenever possible, Heather took the opportunity to ask her students questions that helped them move beyond a superficial understanding. For example, if students were able to answer a question easily, Heather made sure to ask another, deeper question to make sure that her students really understood the material.

Carolyn wrote after another observation about the importance of “questioning” to understand the depth of a student’s thinking. Skilled questioning can also create the structure for student exploration. Carolyn commented on the importance of questioning to student learning:

Heather’s teaching continually reminds me how important questioning is to student learning and development. It is imperative that as a teacher I hold my students accountable for what they are thinking. Not only does it help the students, I have found how much it helps me to know how well students understand a concept. In the lesson, Heather introduced the “problem of the week”, which students typically complete every two weeks. She put the problem
on the board and asked students to share their thinking with the rest of the class. She asked her students to clarify and explain their thinking, but never told them whether or not their answer was right or wrong. This also helped the students who didn’t know where to begin or who were confused by the problem. As a teacher, my natural inclination is to “jump in” and lead the students in the right direction, but I am finding that the more I watch Heather teach in this way, the more I realize how important it is that I do not do that, and instead I let the students explore first… Often times I realize that I ask students questions, and if they know the answer, I don’t go further. After watching Heather, I realized that this is not good enough. Whenever possible, I need to make my students think critically.

Susan (grade 1) wrote that she had come to appreciate the importance of good questioning skills and how difficult a skill it is to master:

I was interested in the kinds of questions she [mentor] asked her students in order to elicit more information. Questioning is a struggle for me in that it is usually so laborious. No matter how hard I try, how many questions I ask, most children don’t want me to know their thinking. They just want me to know that they know the answer. In her class, Linda [mentor] asked questions such as, “How many combinations do you have”? “How many could you have”? More importantly,
she asked the powerful question, “How do you know when you are done with all the combinations”?

….I continue to think about discussion in the classroom – how hard it is for first graders to formulate questions, to share their thinking! I’ve noticed that if you pose the question in a “non-threatening” way, in a way that shows that I am just as curious and without answer as they are, then students tend to have the desire to explore and to take risks. This “vulnerability” I will continue to display to my students.

Jane (grade 5) wrote about learning the importance of follow-up questions:

After observing this lesson, I noticed that the most important questions asked were often clarifying questions, which encouraged kids to explain their thinking more fully, thus, pushing them to use mathematical reasoning to explain how they decided upon a method for solving a problem or a strategy they discovered. Observing Heather [mentor] I also noticed that she often answered students’ questions with new questions or involved another student to assist in the answer.

Jane observed that the value of a teacher insisting that a student explain his answer helped students to understand what they know in a new way, “I also heard students that clearly excelled in computation struggle to justify their reasoning and in doing so made new realizations”.
Connections to Prior Knowledge and Other Subject Areas:

All of the teachers in the study commented on the importance of building new concepts based on the prior knowledge of students and making explicit some of these connections.

Barbara (grade 4) commented, “I learned that you have to connect a student’s past knowledge of concepts with the material at hand. Showing a student how this new concept builds upon prior concepts will help them greatly”.

Carolyn (grade 5) commented on what she learned about making mathematical connections:

Watching Heather [mentor] also enabled me to learn more about mathematical connections and making connections with past knowledge. Many of the students were able to solve the division and multiplication clusters because of their previous mathematical knowledge. For example, one student was able to figure out that 4 x 25 equals 100 because he knew that there are four quarters in a dollar. Other students were able to make connections based on their knowledge of simple multiplication and division rules.

Jane (grade 5) recounted a specific example of a student who was able to explain with the help of his teacher how he calculated 40 x 5 = 200 mentally:
He knew that \(4 \times 5 = 20\) and then he put the 0 on the end and made it 200.

Heather [mentor] challenged the student to explain how he could simply ‘put the zero at the end’ and to explain himself further. One boy in the class explained that he put the zero someplace in his mind while he calculates the rest of the problem and then he pulls it back out when he needs it.

Mary (grade 1) learned, “Another idea was to connect what they’re doing in math to what they do in their journals; the drawing and math equation match, just like the writing and illustration match”.

Carolyn (grade 5) further commented, “Watching Heather [mentor] also enabled me to learn more about mathematical connections and making connections with past knowledge”.

The fifth grade teachers also wrote about the mathematics connections their mentor made to other subjects, most notably, literature. Carolyn (grade 5) wrote about the lesson where her mentor used literature to launch a new concept:

Heather [mentor] showed us a unique way to incorporate literature into our math curriculum. She read to her class *Anno’s Mysterious Multiplying Jar*, which is a short picture book that introduces the concept of factorials. What I liked most about this lesson was that it was a really engaging and simple way to explore a concept that is difficult for most children and adults to understand. Almost all children love and appreciate storybooks, so when it is possible to incorporate
them into a subject that many children don’t like, I think that it is extremely important.…

Another aspect of this lesson that I enjoyed was that the book focused on a very thought provoking question that required deep mathematical thinking and discussion among students. As the students broke off into groups, I was able to hear a lot of interesting conversations. Although most students weren’t familiar with the term “factorial”, I could tell from the discussions that almost all of them understood the underlying meaning.

Differentiating Instruction:

At some point in their journals all of the teachers wrote about differentiating instruction and what they learned during their observations. The first grade teachers highlighted the “123 folders” that their mentor used to provide students with practice problems at three levels of difficulty. They also commented on using math centers as a tool to differentiate instruction.

Susan (grade 1) wrote about math stations as a strategy to differentiate:

Today was very helpful for me. This visit was to show us how one grade one teacher runs math stations in her classroom. I was especially interested in this visit because I still have yet to form my own math centers and have been trying to come up with stations that meet the needs of my high-end students as well as my low-end students.
Susan (grade 1) wrote about a lesson in which her mentor changed an addition problem from the usual form of finding the sum of two numbers to a problem in which one of the addends was missing. This change in the problem was challenging to all of the students in the class.

I am awed by my peer’s ability to “stretch” the activity by simply asking the student to change one aspect of the problem. For example, one of the questions was a word problem that asked the student to combine the 2 numbers. Linda [mentor] changed the problem so that the answer was a missing addend. This was much harder because it did not follow the formulaic working of story problems. I keep this kind of “tweaking” in mind – it is a very subtle but powerful form of differentiation.

Jane (grade 5) recounted that she had in her own class “used Heather’s [mentor] suggestion of giving different groups [cluster problem] sheets of varying difficulty” to address the ranging need for challenge among her students. Students were grouped for this activity by ability. The whole class received the same instruction and examples, but the groups worked on problems of different difficulty.

Jane commented on the “Problem of the Week” lesson, which involved actually three problems of varying levels of difficulty:
There were three questions that require the same type of mathematical thinking, but at different ability levels. One problem provided some scaffolding via a repetitive pattern in which the solution seemed accessible even without a complete understanding of the concept involved. The other two problems increased in difficulty and asked the solver to use mathematical reasoning and their knowledge of numbers and patterns to replicate Gauss’ Theory….It was interesting to watch students grapple with these problems and try to figure out an approach to solve it [the problem they were given] in a group.

*Vocabulary Building:*

All of the teachers commented at least once in their journals about the importance of students learning and using correct mathematical vocabulary.

Barbara (grade 4) reflected on a graphing lesson in her mentor’s classroom in which vocabulary was an important component of the lesson:

Through questioning, Meredith [mentor] allowed the students to look very closely at the data. They were very engaged in the lesson. Meredith connected this lesson to a graphing lesson that she taught prior to this one. This was incredible – every child in her class knew the vocabulary!….I realized that I have to spend a great deal of time on vocabulary [graphing]. I have covered it but I’m not sure if my students really comprehend the meaning of each word. I plan to do this exact lesson with my students.
Carolyn (grade 5) observed her mentor review relevant vocabulary to the lesson. The mentor expected students to use the proper vocabulary in their discussion as a class and during group work. Carolyn learned what is possible to expect from students in this grade:

Heather [mentor] asked students to revisit vocabulary from their Prime Time unit and then apply their knowledge of these vocabulary terms in small groups….Throughout their discussions students were using appropriate vocabulary to determine which numbers to cross off [the hundreds chart]….It was very informative for me to hear the students discuss their thinking and reasoning….After seeing how successful this lesson was in Heather’s classroom, I decided to use it as a method of reviewing these terms with my class a few weeks after we ended the Prime Time unit. I think it is a great way [using an activity which requires the use of vocabulary] without drilling the students with definitions. It allowed me to see which students were able to retain these terms and which students still needed more exposure and discussion of them….I really love how Heather uses “big math words” with her students such as discourse. It is evident from her students and their work that they are not too young to be exposed to these types of activities.
Jane (grade 5) commented, “I was intrigued by their [mentor’s students] continual use of the vocabulary, almost without thought, as they were involved in the activity”.

**Group Work/Learning:**

Several teachers commented on how helpful it was to observe how their mentor was able to structure group work that was productive and engaged all of the students in discussion.

Jane (grade 5) wrote about the importance of hearing the instructions that an experienced teacher gives her students before group work:

It was wonderful to watch students work furiously and determinedly in groups to solve a problem….In my classroom, there are times when group work just doesn’t seem to pan out. Sometimes students just don’t put their all in to their work or they only complete part of the work. Other times, students from my class simply can’t handle the open-endedness that group problem solving can require.

Observing another teacher and another class provides me, as a new teacher, with the opportunity to hear the instructions given for the students to carry out their inquiry work. It is wonderful to be inside someone else’s classroom and I always feel inspired after watching Heather [mentor] teach.

Carolyn (grade 5) commented on the importance of structure for groups to be successful after observing a lesson in her mentor’s class, “There was a facilitator for
each group, who encouraged discussion, and every student was asked to explain in words why he/she was crossing off certain numbers and leaving others [finding prime numbers in the 100’s chart]”.

*Time Organization:*

Mary (grade 1) commented on how helpful it was to observe her mentor organize the hour of mathematics instruction:

Math began with a whole group lesson (with lots of questioning of students) and then small group work on the big idea. (Good, I do this too.) As children finished, they immediately retrieved folders, which contained work, designed to meet individual needs. After this, TERC math games were available. There was lots of good math conversation between Linda [mentor] and the children as well as among children. Children worked well together and moved independently through the activities. Everyone did their best and got what they needed – perfect….I have started to plan each lesson in more detail now, yet remain flexible enough to take advantage of new/different ideas that may pop up in the students’ conversations.

Barbara (grade 4) commented on what she learned from her mentor regarding how to allocate time in a lesson:
Meredith did a lesson on division stories. I had taught this lesson the week before so it was great to see the things that were both similar and different. One thing that I took away from this lesson was that students need more time to come up with good stories. I set a ten-minute timer when they [her students] were working with a partner to complete the problems, while Meredith gave them double [that amount of time].

Confidence

In their journals, teachers described their increased confidence in their journals as feeling empowered to teach a mathematics lesson in their own classrooms or by being motivated by their mentor and fellow teachers. As revealed in an earlier comment, one teacher felt “inspired” by her mentor.

Susan (grade 1) wrote, “All in all, I am continuing to feel comforted yet motivated by my math mentor and fellow teachers. It has been very helpful to be part of this team”.

Carolyn (grade 5) commented, “Having watched Heather [mentor] teach this lesson [factorials using *Anno’s Mysterious Multiplying Jar*], I feel well equipped to teach it in my own class, and to try and incorporate more literature in math whenever possible”.

Classroom Practice

The teachers identified several pedagogical skills that they learned to teach mathematics that could be applied to other subjects as well: questioning skills, effective group instructions and structures, strategies to develop mathematical vocabulary,
organization of time, and strategies to differentiate instruction. All of these strategies affected their classroom practice.

Additionally, the first grade teachers commented positively on a practice they observed in a peer’s classroom in which all of the first grade students at the particular school were organized into two ability level groups for a lesson. They felt that students at all levels enjoyed and benefited from working with students from the other class. This practice of blending classes for extension and remedial work varies by school and grade in the district.

Susan described the mentor meeting previously referred to that she and her fellow first grade teacher (also in the Math Mentor Program) hosted at their school, “We designed ‘2 room stations’, where Lilly (fictitious name) took those students who were ‘low to mid-level’ in their skills, and I took those ‘middle to high level’ students. It was a successful day, one that offered each student a chance to be successful”. Sandra commented after observing the “2 room stations” lesson, “The combining of classes was something that we would like to implement in other schools”.

Mary (grade 1) wrote after the lesson, “Sandra and I have talked about sharing kids they way they did at Susan and Lilly’s school. I had been worried about the kids traveling so far down the hall, but they made it work for their kids, so maybe we should try it”.

Research Question 2 - How did the various components of the Math Mentoring Program contribute to new teachers’ perception of their improved content knowledge, pedagogical strategies, confidence, and classroom practices?

All of the teachers frequently referred to the benefits of observing their mentor teach a mathematics lesson. Frequently, the mentor teacher involved the new teachers in the lesson by having them work with a group of students during part of the lesson. Teachers also commented on the benefit of watching their fellow teachers work with students. Additionally, the first grade teachers wrote about the benefit of watching their peer teachers work with their students when the teachers started to rotate among each other’s classrooms to observe a mathematics lesson half-way through the year. The teachers felt that all of these experiences helped them expand their pedagogical knowledge and repertoire.

Effect of Observations

Mary (grade 1) commented on the benefit of observing in other teachers’ classrooms:

I love visiting other people’s classrooms to see the overall environment and their teaching styles, and to get new and improved ideas for math activities, including the set-up and format of any worksheets. We have also had time at each meeting
to discuss overall behavior management and to help each other with kid-specific
difficulties/challenges. These meetings are an amazing support mechanism!

Sandra (grade 1) said, “It was reassuring to know that other teachers are
struggling with similar issues/student concerns”.

Susan (grade 1) wrote about the benefit of watching other teachers work with her
students:

I appreciated my peers’ assistance. I watched them as much as I observed my
own students. What I noticed was how the teachers asked probing questions, how
they engaged the students in discussion. I am also awed by my peers’ ability to
“stretch” the activity by simply asking the student to change one aspect of the
problem.

Carolyn (grade 5) commented on the impact of observing in her mentor’s
classroom:

Today’s observation of Heather’s class was a very valuable opportunity to witness
the social nature of learning in mathematics. From observing Heather, I was able
to learn a great deal about questioning and how questions can enrich our
mathematical discourse.
Jane (grade 5) wrote, “Observing another teacher and another class provides me, as a new teacher, with the opportunity to hear the instructions given for students to carry out their inquiry work”.

**Effect of Group Discussions and Sharing**

All six of the teachers mentioned at least once in their journals the benefit of having regular discussions with their peers about the mathematics curriculum and student learning. The teachers also commented that they benefited from their mentor and peers sharing materials. Generally, the shared materials referred to in the journals were worksheets, group directions and rubrics, and project information. Several teachers said that the post-observation discussions were helpful because they were able to bring their teaching problems/concerns to the group for their support and insight.

Mary (grade 1) wrote, “Our follow-up discussion was interesting because with so many adults, we were able to see a lot about how each kid processed the tasks. If only there were multiple adults everyday”!

Sandra (grade 1) wrote regarding her experience of group discussions, “It was reassuring to know that other teachers are struggling with similar issues/students”.

Sarah (grade 1) commented on the value of the advice she received from her mentor:

It was also helpful to have discussions with Linda [mentor]. I have been struggling to come up with ways to help my low students (students who still are
not conserving). She gave excellent advice: some students need to memorize and be given explicit directions before they can make connections.

Mary (grade 1) also wrote about the value of group discussion, “We had time at each meeting to discuss overall behavior management and to help each other with kid-specific difficulties/challenges. These meetings are an amazing support mechanism”!

**Effect of Journal Keeping**

None of the teachers mentioned the benefit of keeping a journal as an aspect of the program that contributed to their increased content knowledge or pedagogical skills.

**Effect of Reading Math Articles**

Only one teacher specifically referred to the effect of reading math related articles. She briefly referred to an article written by John Van de Walle (math educator) as being helpful.

**IV. Interviews**

The researcher interviewed the six teachers in the case study in June. The teachers were asked the same set of questions in a semi-structured format that allowed for follow-up questions or requests for clarification. The interviews ranged in time from about twenty minutes to forty minutes, with most close to forty minutes. The questions asked were designed to elicit insights into their perceptions about the mathematics and
mathematics pedagogy that they learned from their experience in the Math Mentor Program, as well as, their perception regarding their confidence to teach the mathematics curriculum. Questions also probed the changes they observed in their classroom practice over the year. They were asked to comment on what aspects of the Math Mentor Program they felt were most helpful in supporting them as a new teacher.

The findings from the interviews are presented through the framework of each research question and the themes related to each sub-question.

**Research Question 1 - How did the Math Mentoring Program affect participating teachers’ perception of their ability to teach the mathematics curriculum, Investigations Into Number, Data and Space?**

**Math Content Learned**

The responses to the question of what mathematics they learned as a result of their participation in the program varied by grade level. Teachers in the upper grades recounted mathematics concepts that they gained deeper insight into, while first grade teachers talked about the mathematics pedagogy they learned. First grade teachers felt that the mathematics they taught was fairly simple in concept. The challenge was to learn different ways to present a concept. They felt that they learned new approaches to teaching basic concepts, such as addition, through observing their mentor.

Sandra (grade 1) said that she did not learn new mathematics concepts in the program but rather learned about the pedagogy of teaching mathematics:
I have to say that I didn’t learn any mathematics because it’s the first grade curriculum and as an adult it is pretty basic…the TERC program is very different in theory from what I had taught previously, which was based on a textbook that we plowed through. I have learned more about children’s thinking, listening to their thinking, and valuing the process of learning rather than just having them memorize what they are suppose to know….I spent much more time than I had in the past on thinking about addition, what is addition, not just the plus sign. They [her students] weren’t memorizing any math but understanding what is means to combine things….I’ve come to value that much more than I have in the past.

Mary (grade 1) said, “understanding (mathematics) and being able to teach it are two very different things for me”.

Jane (grade 5), in response to the question regarding the mathematics learned, recounted a lesson her mentor taught to demonstrate how to make mathematics accessible to children who are at different levels of understanding. The class was asked to develop a theory regarding how to generate triangular numbers. Jane said:

I had done it completely wrong because I was just looking at it from a logical viewpoint and not using and understanding the numbers. As I watched the students I realized that I was missing a key part of the math. It was so amazing to watch and learn something from the students who got the correct answer to the problem while I got the incorrect answer. And it happened again when she [her
mentor] was reading a story about a magical multiplying jar to learn about factorials. I hadn’t realized that there was a straightforward way to calculate the answer to the problem ….This was just another example of how students in the fifth grade are able to think mathematically at such a high level. During this lesson I was learning a little mathematics and also the way you ask questions to probe students understanding.

Later in the interview, Jane talked about deeper understanding she had of the relationship among certain fractions she gleaned as a result of her observation in her mentor’s classroom:

Now after using the math program that we use and then just watching the way that Heather [her mentor] teaches math, I feel that I have a deeper understanding of how these things [math] work. For example, fractions are something I understand, but then to apply it, to teach in a way that students understand that 2 ½ cups is the same as five ½ cups is different. I’m really learning it all over again. The visual component [of teaching math concepts] has been great for me because I’m always filling in those holes that I’ve had throughout my life from learning just how to do it [an algorithm]. Back then you didn’t ask questions. If I were to go back and take math as we teach it today, I would probably have a better grasp of what they were talking about, not just how to plug numbers into a formula.
When asked what mathematics they would want to know more about after completing their first year of teaching the mathematics curriculum, the answers varied. Teachers in first grade focused more on how to teach a mathematics concept better rather than understanding the concept itself better. Teachers in the upper grades focused more on understanding and deepening their understanding of certain concepts in mathematics.

Susan (grade 1) wanted to learn different approaches to teaching place value to help her struggling students. She also added that she wanted to learn how to teach time better. Sandra (grade 1) indicated that she also wanted to learn how to better teach the supplementary units on time and money.

Jane (grade 5) said that she wanted to know, “…more about probability and ratios to have a deeper understanding of both so that I can teach them even more creatively…I wasn’t able to take the topics to a place where we could have good discussions in class about the similarities and differences”.

In general, the teachers could identify only a few mathematics concepts that they understood better as a result of their observations in their mentor’s classroom, but they felt that their deepened understanding of those concepts improved their ability to teach them. When describing new mathematical understandings they did not separate the concept from the pedagogy of teaching the concept.
Math Pedagogy Learned

Regardless of grade level, all of the teachers reported changes in their instructional practice due to their participation in the Math Mentor Program. The changes most frequently identified had to do with their improved questioning ability, increased allowance of “wait time” for student answers, and acquired discipline to suppress their urge to introduce a mathematics concept with explicit instruction. Other changed or improved instructional practices included learning how to differentiate lessons, set up tiered learning centers, and organize students into working groups. All of the teachers felt that the cohort discussions regarding the curriculum and the shared materials improved their lesson planning. Several teachers mentioned that it was helpful to see how an experienced teacher was able to weave and teach mathematical concepts through other curriculums or non-math projects.

Questioning

Susan (grade 1) commented on the importance of observing her mentor ask questions during a mathematics lesson:

It was especially helpful that I was able to observe how Linda [mentor] engaged the children in discussion and asked questions that probed their thinking….It was really interesting to hear her ask her students questions. I actually wrote the questions in my journal and tried to replicate those questions in my class, which became my core questions to always ask my students.
Sandra (grade 1) acknowledged that she now “values much more the thinking process [encouraged through questions] and I have taken a big step away from memorization and that kind of teaching”.

Susan (grade 1) commented on her improved ability to empower her students to explain their thinking:

I’m not very good at math, but I learned to love math during my student teaching experience while working with a supervisor who instilled the wonder and awe of math. So while my beliefs about math have not changed this year, I have improved in how to have real discussions and empowering kids to try to explain their thinking, not just explain but take it to a new level. I love this approach [to teaching math], which I never experienced myself.

Mary (grade 1) talked about learning how important it is to elicit and encourage student thinking:

Our group conversations were just wonderful because we all would see different kinds of things [with the students]. We talked about how to pull stuff out of kids and get them to think more in the way that we would like them to think about math. I didn’t learn [math] that way and it’s so hard for me not to just tell them what they need to know….Learning to talk in a ‘TERC’ way to get our kids to do
some independent, mathematical thinking...was difficult and took a lot of practice.

*Wait Time*

Barbara (grade 4) commented on the importance of providing students with sufficient time to work through a problem and to avoid, at least initially, explicit instruction:

I learned that [in math] you really need to give students time to really stop and think and even struggle with it to work their way through the problem and allowing enough time for them to do it....Having students work through it [the math problem] and not being so explicit in the beginning was definitely different than how I taught math before....Less modeling and letting them figure it out on their own was hard for me to get used to, along with all the questioning that you need to do and getting them to explain their thinking – all were challenges.

*Differentiating Instruction*

Jane (grade 5) said that she struggled with how to differentiate instruction to address the needs of those students who quickly understood a concept and those who required more instruction and practice. She also found it difficult to offer students computational practice problems that met the needs of all the learners in her class without relying on worksheets. Her mentor showed her group a simple method to develop
students’ math facts that was both fun and challenging and offered the benefit of a quick assessment.

Heather [Jane’s mentor] suggested that we write a box on the board and put a number in the middle along with an addition, subtraction and multiplication sign. Students have to come up with as many ways as they can to get that number using those signs. And that was great because they could work on the problem for five minutes or fifteen minutes… the kids thought that it was a game and it was a challenge for everyone…This was a reminder that there are other more creative ways to teach that I need to build into my practice.

Susan (grade 1) learned from her mentor an easy way to differentiate instruction:

My mentor had three folders in her classroom and in each folder there were different worksheets depending upon the skill of the student…I actually have them in my classroom too. It is just an easy way to differentiate additional practice if students finish their work early. They can go to the folders and be productively engaged, they can work with other students cooperatively…this is one way the program has affected my teaching practice.

Mary learned from her mentor how to set up learning centers but has not had the time to actually implement the centers. She plans to organize activities for her centers
over the summer. Mary recounted the purpose of the math centers as described by her mentor, “Math centers allow for more independent follow-up work at different levels - to challenge the kids who need it and to provide extra practice for kids who need that.” Mary felt that the centers would offer her the opportunity to provide a range of activities to address the wide-ranging learning needs of her students.

*Group Learning/Other Representations*

Carolyn (grade 5) commented, “I’ve learned how you set up groups, how you ask questions, and how you execute a lesson.” She recounted repeating the same lesson her mentor had taught on fractions, which involved the students representing a list of fractions pictorially as a prelude to a discussion of least common multiples. “Each student was asked to demonstrate every fraction on a list either on a graph or by drawing it….I think that for many kids this really helped them understand the concept”.

*Relating Math to Other Subject Areas*

Jane (grade 5) expressed her appreciation of learning how to relate mathematics to other curriculum areas:

Another thing that I liked was the way she [mentor] was able to connect math to different subjects through some of the projects that she had going on, whether it was reading a story book or the bridge building project that we observed last week and the way that they are connecting math with science and real life situations….I
feel that there is often not enough time for those hands-on types of projects in math, so it was great to see that….She shared different ways that you can find similar projects that maybe aren’t quite as time consuming [as the bridge project].

**Confidence**

The issue of improved confidence in teaching the mathematics curriculum through participation in the Math Mentor Program was addressed indirectly by the interview questions. Teachers were asked to describe how their beliefs about mathematics and teaching mathematics changed over the course of the year. All of the teachers interviewed spoke about their improved ability to elicit through questioning their students’ thinking, which they understood to be an essential skill necessary in considering whether they were successfully teaching the mathematics curriculum.

Susan commented, “I think that I am a better questioner. I’m better at thinking up questions that really get students to think such as coming up with the rules for addition and subtraction, which we post in the room”.

In a follow-up question, Mary was asked if she enjoyed mathematics. She responded:

No, I never did. I think that when I went to school in the 60s, math was just memorization – you learned, did some worksheets, and then took a test. I never liked any of that about my schooling. That was one of the reasons I wanted to be a teacher. I felt that there had to be a better way to do this [teach math]….Having
the content knowledge is one thing, but knowing how to convey it in a helpful way to children so that kids understand [the math] intellectually is really different….Again, that was another concrete thing about the math mentor program – we could work and then talk about it and right away I could go back to my classroom with a bunch of new ideas including how to keep asking questions and asking questions to get the kids thinking. There are lots of things I will teach differently next year.

Additionally, teachers expressed in different ways a new enthusiasm for learning mathematics as well as teaching mathematics. In response to the question concerning her changed beliefs about mathematics and teaching mathematics, Jane (grade 5) said:

I would say that thinking back now to when I was an elementary student and high school student, math always came very easy to me in the early grades. Probably until I started geometry and precalculus in high school it was easy. I understood it. I got it. I didn’t learn or need to learn any of the strategies that I now see them [students] using. I think that they are fantastic. I wish that I had learned this way… when I got into deeper mathematics that was where I fell off because I didn’t have a mathematical understanding. I knew how to look at numbers, do computations, get the correct answer, check my answer and move on. Now after using the math program that we use and then just watching the way that Heather [her mentor] teaches math, I feel that I have a deeper understanding of how these
things work….So it’s been really great for me to just take the time to really listen to the way someone is teaching and to think about understanding it [the math], and also to have math conversations where you are talking about math. I love to listen to my students talk about math. I can’t recall ever talking about math in school and I think it’s great that they are excited to share their thinking on problems. It’s been great to listen in [to mentor’s students] and sometimes hear a student look at a problem in a way and say, ‘Oh, I never would have approached it that way’….This has really changed my entire thinking about math – it’s now not math the dry subject…there are different ways to approach a problem and there are different ways to understand a solution.

**Classroom Practice**

In addition to their new understandings about teaching mathematics, the teachers interviewed identified other classroom practices that they implemented in their own classrooms as a result of their participation in the Math Mentor Program.

Fifth grade teachers mentioned, in different degrees of detail, that they learned how to have students work in groups, which was a practice that was useful regardless of content area. Carolyn (grade 5) said,

I think the way Heather [her mentor] has her students work together is just amazing. They just work like they have been working together for years. She
doesn’t have to say anything; they know exactly what to do…this has been one of the biggest changes I have made in my own classroom.

Jane (grade 5) mentioned that she learned the importance of wait time for teaching mathematics or any subject:

At the beginning of the year when we met with her [mentor] she talked about the importance of wait time, which really stuck with me. I really tried to use it [wait time] throughout the year as many students in my class were very impulsive and just wanted to jump on things [questions] because they knew the answer or just wanted to be the first to say something even if it was incorrect….So we really tried to practice wait time to allow everyone time to think about it awhile….My mentor’s suggestion to allow wait time influenced me a lot. I was able to let the students who are a little bit shy or quiet or who think a little bit more clearly and work things out carefully to have their say as well.

*Research Question 2 - How did the various components of the Math Mentoring Program contribute to new teachers’ perception of their improved content knowledge, pedagogical strategies, confidence, and classroom practices?*
**Effect of Observations**

Without exception, the teachers interviewed emphasized that the opportunity to observe a skilled, veteran teacher or each other teach a mathematics lesson was the most influential aspect of the Math Mentor Program on their practice, followed by the discussions with their peers and mentor before and after an observation.

Several teachers mentioned the benefit of knowing each month where their peers were with respect to the curriculum-pacing guide and to have the opportunity to share concerns. Several teachers commented on the security of knowing that their mentor was available for questions at any time. Teachers appreciated the opportunity to share materials and ideas. One teacher commented on the value of keeping a journal to help her think more deeply about her experience.

Carolyn (grade 5) made these comments about her experience and her mentor,

I think that the greatest asset (of the program) is to have the support of the other fifth grade teachers and Heather [mentor] – to see someone who has been teaching for so long … to see how you set up groups, how you ask questions, how you execute a lesson…. I learned that you are constantly learning no matter how long you have been doing this.

Jane (grade 5) commented, “One of the things that I learned the most from was observing a lesson with Heather [mentor] …particularly when she taught a lesson about a problem that we taught later”.

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Barbara (grade 4) said, “I definitely think that observing was a really great piece of the program”.

Susan (grade 1) commented on the value of observing her mentor:

I think that by following Linda’s [mentor] example …just constantly questioning kids, constantly giving them the power to construct their own ways of getting the solution to a problem; it really did create a learning environment so that kids feel that they could make mistakes….So, I feel that I have been successful in that I have hopefully created a learning environment.

First grade teachers decided as a group later in the year to also observe each other teach a lesson. Sandra (grade 1) commented on that experience:

I thought that it was helpful that we could see someone else teach a lesson and then take it back [to our classrooms] and the very next day do that same exact thing [lesson]….I think that it was just so helpful to see other teachers [teach a lesson], observe the language and the way they were addressing the same problems that I was having….I think that it was really helpful observing each other not in a judgmental way but in a way that was just brimming with ideas.

Mary (grade 1) also commented on the value of being in other colleagues’ classrooms to observe a mathematics lesson and to discuss their observations, “We
decided that we should actually work in each other’s classrooms, so that’s what we did, and then our conversation afterwards was just wonderful because we all would see so many different kinds of things”.

Sandra (grade 1) commented on the value of observing in her peers’ classrooms:

We set up a schedule so that every month we would go to the scheduled teacher’s classroom and work with the kids so that we weren’t just observing. I appreciated that it wasn’t judgmental – we were just working with the kids….It was great for me to see that everyone was on the same page, we were all at the same place, our kids were struggling with the same things across the board.

**Effect of Group Discussions (and Sharing Materials)**

Jane (grade 5) also commented on the value of the group discussions, “I always felt as though I was behind the other teachers, so it was nice to get together with a group of new teachers to know that some people were on pace and other people were going at a slower pace”.

Carolyn (grade 5) concurred in her interview that she valued knowing where everyone else was in the curriculum, “I just liked having the support of seeing where everyone else across town was in the curriculum and how our kids were doing….I think that it is a good feeling to kind of know what every one else is going through in their first year”.

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Jane (grade 5) appreciated the sharing opportunities the program offered, particularly because of the limited time teachers had during a normal school week to share and discuss ideas with colleagues:

Due to the limited time available in staff meetings, we don’t get to share as much as we would like, so one thing I valued about the Math Mentor Program was being able to ask someone a question about when to use this, how does it fit, and how to teach a math lesson….because as a new teacher I never get the time to check in with other teachers because I’m so overwhelmed…and to be forced to have that time is good for us….You can get very isolated in your own classroom and you almost have to force yourself to go out.

Sandra (grade 1) also appreciated the opportunity to share materials, “We made kind of a rule that if there is something we liked when visiting each other’s classrooms we would make a copy”.

*Effect of Keeping a Journal*

Only one teacher commented on the benefit of keeping a journal. Susan (grade 1) commented that writing a journal “forced me to think deeper than maybe I would have, especially if I did it right away….It was also nice that what when we had our last meeting it was nice to hear what other people said…that part was also helpful”.
Effect of Reading Math Articles

No one mentioned the benefit of reading any of the offered mathematics articles in their interviews.

V. Questionnaires

The teachers were given two questionnaires to complete during the school year – an initial and end-of-year survey.

Initial Questionnaire

Due to a misunderstanding regarding when the questionnaires should be administered, not all grades completed the initial survey in the fall. A second “initial survey” was sent to all participant teachers in January. The January questionnaire was identical to the original survey except that teachers were asked to rate their confidence in teaching the mathematics curriculum not only in September but also in January using a ten point Licher scale with “1” representing “no confidence” and “10” representing “very confident”. Table 3 below displays the responses of the six teachers in the study.

Table 3 Initial Survey

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Grade</th>
<th>September Confidence</th>
<th>January Confidence</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carolyn</td>
<td>5</td>
<td>4</td>
<td>6</td>
<td>+2</td>
</tr>
<tr>
<td>Jane</td>
<td>5</td>
<td>7</td>
<td>8</td>
<td>+1</td>
</tr>
<tr>
<td>Barbara</td>
<td>4</td>
<td>3</td>
<td>5</td>
<td>+2</td>
</tr>
<tr>
<td>Susan</td>
<td>1</td>
<td>5</td>
<td>8</td>
<td>+3</td>
</tr>
<tr>
<td>Sandra</td>
<td>1</td>
<td>6</td>
<td>8</td>
<td>+2</td>
</tr>
<tr>
<td>Mary</td>
<td>1</td>
<td>4</td>
<td>7</td>
<td>+3</td>
</tr>
</tbody>
</table>

Average: +2.2
All teachers in the Math Mentor Program completed the questionnaires. By way of comparison, the average change for the six teachers (not in the study) in the Math Mentor Program who had previous experience teaching TERC’s *Investigations Into Number, Data and Space* either at a different grade or in another out-of-district school was +1.0 as contrasted to +2.2 for the teachers in the study (who had never taught the mathematics curriculum).

The questionnaire contained one open response question: What concern(s), if any, do you have or did you have about teaching mathematics this year? What additional support in teaching mathematics would be helpful to you?

The responses of the six teachers in the study are displayed in Table 4 below.

**Table 4  Responses to Open-ended Question - Initial**

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Grade</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carolyn</td>
<td>5</td>
<td>Other resource books with homework and practice problems would be useful – these are hard to find and often expensive. It would be useful to see a few of the math lessons being taught <em>before</em> the school year begins.</td>
</tr>
<tr>
<td>Jane</td>
<td>5</td>
<td>At this point, I’m concerned about keeping pace with the other two 5th grade teachers at my school and matching my instruction and practice to theirs. Until I familiarize myself with the pacing chart, benchmarks etc., it’s hard to say what [I need].</td>
</tr>
<tr>
<td>Barbara</td>
<td>4</td>
<td>TERC is a program that gets easier to teach with experience. With time, I think that I will become more confident.</td>
</tr>
</tbody>
</table>
Specific strategies (outside of TERC) to help students who struggle. There is a lot of language in TERC, which is hard for ELL and those students with language delays.

I would like more guidance in teaching the supplemental units. I’m having a hard time understanding how these units can be taught using the TERC philosophy.

I am most concerned about creating an environment of support and collaboration and investigation in terms of attitude, materials, questioning (rather than telling). I feel that I am doing a much better job of this and am more aware of the planning necessary for it. The Math Mentor Program and TERC really offer all the support I need – I wish we had TERC materials for all the [math] units.

### End-of-Year Questionnaire

Five of the six teachers in the study completed and submitted to the researcher the end-of-the-year questionnaire. The teacher who did not complete the questionnaire left the district at the end of the year.

The questionnaire consisted of two parts: (1) a chart containing nine statements for which the teachers had to select one of four responses – strongly agree, somewhat agree, somewhat disagree, or strongly disagree; and, (2) five open response questions. Table 5 displays the responses of the five teachers.
Table 5 Responses of Teachers

<table>
<thead>
<tr>
<th>My participation in the Math Mentor Program has helped me:</th>
<th>Strongly Agree</th>
<th>Somewhat Agree</th>
<th>Somewhat Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Feel more confident teaching the TERC math curriculum.</td>
<td>2</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Deepened my understanding of the math involved in observed TERC lessons.</td>
<td>3</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Diagnose and evaluate my students' understanding of math.</td>
<td></td>
<td></td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>4. Deliver math instruction to:</td>
<td>2</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Develop a supportive network in my cohort group of teachers.</td>
<td></td>
<td></td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>6. Feel supported in my development as a math teacher.</td>
<td></td>
<td></td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>7. Plan and design math lessons.</td>
<td>3</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Improve my math knowledge.</td>
<td></td>
<td></td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>9. Improve mathematical discourse in my classroom.</td>
<td></td>
<td></td>
<td></td>
<td>5</td>
</tr>
</tbody>
</table>
In order to compare each of their responses to the question of confidence on the initial questionnaire to the end-of-the-year questionnaire, the four response choices on the end-of-year questionnaire were converted to a lecher number. The four categories were corresponded to a group of numbers in the range from 1 to 10.

<table>
<thead>
<tr>
<th>Category</th>
<th>Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>strongly disagree</td>
<td>1-2</td>
</tr>
<tr>
<td>somewhat disagree</td>
<td>3-5</td>
</tr>
<tr>
<td>somewhat agree</td>
<td>6-8</td>
</tr>
<tr>
<td>strongly agree</td>
<td>9-10</td>
</tr>
</tbody>
</table>

The number associated with a particular category was the average of the numbers in the group. For example, “strongly agree” converted to 9.5.

Table 6 displays the confidence numbers from September to June for the five teachers in the study who returned their questionnaire. Because of the conversion of once scale to another scale, the average obtained by subtracting the September score from the June score (3) is slightly different than average of the change column (2.8).

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Sept.</th>
<th>June</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carolyn</td>
<td>4</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td>Jane</td>
<td>7</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>Susan</td>
<td>5</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>Sandra</td>
<td>6</td>
<td>9.5</td>
<td>3.5</td>
</tr>
<tr>
<td>Mary</td>
<td>4</td>
<td>9.5</td>
<td>5.5</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>5</strong></td>
<td><strong>8</strong></td>
<td><strong>3.0/2.8</strong></td>
</tr>
</tbody>
</table>
By comparison, the other new teachers (in the MMP, but not in the study) who had prior experience teaching *Investigations Into Number, Data and Space* either at a different grade level or at an out-of-district school had a confidence change of +1.0 as a group from September to June, employing the same conversion formula used for the teachers in the study. This result of +1.0 contrasts to a change score of +3.0/2.8 for the teachers in the study who had never taught mathematics using the TERC program.

**Research Question 2 - How did the various components of the Math Mentoring Program contribute to new teachers’ perception of their improved content knowledge, pedagogical strategies, confidence, and classroom practices?**

Two of the nine statements in the chart section of the questionnaire addressed components of the Math Mentor Program - their feelings about their cohort group and their sense of welcome to call their mentor with questions. The teachers strongly agreed that they had developed a supportive network with their cohort group and that they felt that they could call their mentor with questions.

**Responses of teachers to the open response questions on the end-of-the-year questionnaire:**

One of the five teachers who turned in their questionnaire did not answer any of the open response questions. This teacher moved out of state within days of the close of
school, which may explain why she only partially completed the questionnaire. The charts below, therefore, only contain the responses from four of the teachers.

1. In what ways has this program met your needs?

<table>
<thead>
<tr>
<th>Name</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carolyn</td>
<td>This program has offered me support from other 5th grade teachers in the town and a wonderful mentor in Heather. It has also been helpful to know where the other 5th grade teachers are with the curriculum</td>
</tr>
<tr>
<td>Jane</td>
<td>I found the discussions before and after the lesson more helpful to my mathematical knowledge. During those times, we discussed challenges and successes – and additional ways to teach math that supplement TERC.</td>
</tr>
<tr>
<td>Sandra</td>
<td>Observing other teachers using the TERC methods has greatly influenced my teaching. I feel much more comfortable with the language of questioning my students. I also have grown to see the value of letting children problem solve on their own.</td>
</tr>
<tr>
<td>Mary</td>
<td>Our group functioned in a very collaborative, supportive way. After initially observing Linda [mentor], we all took turns working in each other’s classrooms, sharing materials, and insights about children.</td>
</tr>
</tbody>
</table>

2. In what ways did the program not meet your needs?

<table>
<thead>
<tr>
<th>Name</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carolyn</td>
<td>It took me out of the classroom. More support as a first year teacher would have also been beneficial before the start of school.</td>
</tr>
<tr>
<td>Jane</td>
<td>It was always difficult to leave my own class to go to mentoring, though worthwhile. I wish that there was more time to see what other schools are doing.</td>
</tr>
<tr>
<td>Sandra</td>
<td>I would like more strategies on implementing the supplemental units. I have a hard time seeing how they fit into the TERC model.</td>
</tr>
<tr>
<td>--------</td>
<td>-------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Mary</td>
<td>None</td>
</tr>
</tbody>
</table>

3. Describe three math insights and/or instructional practices that you have learned from your participation in the program and how were they were implemented in your classroom?

| Carolyn | 1) Wait time – how to provide more wait time for all students. Utilized across all curriculum areas.  
2) How to set up students for group work – Heather’s students were models for how to get students to work together as a group. Used as a model for group work in my classroom.  
3) How to ask questions that stimulate thinking, which leads to deeper connections and thoughts. |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Jane</td>
<td>One of the things I liked most was the Problem of the Week that Heather used in her classroom. It was a nice way to include math writing, problem solving and differentiation in one package. I have tried to use MCAS open-response questions to hit at the first two, but, of course, they are not as challenging or leveled so there is no opportunity for differentiation.</td>
</tr>
</tbody>
</table>
| Sandra  | 1) I have a clearer understanding of how to effectively question my students.  
2) I value their thinking process and learned to gain information from their incorrect responses.  
3) I have learned to stop having the kids “memorize” math concepts. Helping them to understand the concepts is much more beneficial in the long run. |
| Mary    | 1) Providing additional work (at varied levels in student folders) and games for children who finish early.  
2) Groupings – have 3-4 homogeneous groups for some activities/units and heterogeneous groups for others. Heterogeneous groups or pairs were useful for initial explanations and for most games.  
3) To reflect at the end of each day - tweaking a lesson already taught for the future and/or tweaking the lesson the next day. |
4. If you were redesigning the Math Mentor Program for next year, what changes would you make?

| Carolyn          | 1) The number one change I would make is to provide teachers with more help and support before the start of the school year.  
|                  | 2) It would also be helpful to have fewer reflections or different topics/questions. It got very redundant to ask and answer the same questions. |
| Jane             | Heather was a wonderful mentor. I would really just hope that all mentors would lead sessions like hers, beginning with a check-in, an exploration of the lesson we would observe, the observation, and then a discussion of all things math during which Heather shared any ideas and resources that she had. |
| Sandra           | I would like to cut back on the amount of meeting time scheduled during the school day. |
| Mary             | None – Initially I was a bit uncomfortable leaving my class for half a day – but the afternoon time was perfect. I prefer to start the day with my students. |

5. What further professional development in mathematics do you need?

| Carolyn          | I need help with working with special education students and those students who gifted and talented (i.e. how to differentiate the curriculum). |
| Jane             | More work with differentiation. Help with creating math centers that are meaningful use of time. |
| Sandra           | Ideally, I’d like to have a formal TERC training. |
| Mary             | More help meeting the needs of higher-level students – appropriate challenges to broaden/deepen their understanding. |
VI. End-of-the-Year Assessment Results

At all grades K-12 in the district, teachers administer common mathematics assessments after major units of study and at the end of the year. In the elementary schools, data is collected after each common assessment for the purpose of tracking the progress of each student in mathematics as well as to provide information to teachers about the relative performance of their students to other students in the same grade. Detailed rubrics guide the correction of all common assessments.

The results of the end-of-the-year common assessment are presented for each grade level represented by the teachers in the study. The student average scores of teachers in the study are compared to student scores of veteran teachers (teachers with two or more years experience teaching mathematics using TERC’s *Investigation Into Number, Data and Space*) at that grade.

**Grade 1 Results**

During the year of the study, there were twenty-one first grade teachers in the district, four of whom participated in the Math Mentor Program. The student mean score on the end-of-the-year common assessment for all twenty-one teachers was 92.5 with a range of 15.6 and standard deviation of .73. The median for this sample was 92.8.

When the student assessment scores for the four teachers who participated in the Math Mentor Program were removed from the sample, then the student mean score for
veteran first grade teachers was 92.3 with a range of 15.6 and standard deviation of .9. The median score was 92.7.

Table 7 below displays the student mean scores for the three teachers who participated in the study as well as the other first grade MMP teacher relative to the student results for the veteran first grade teachers.

Table 7  Comparison of Assessment Means of MMR Study Teachers to Grade 1 Cohort (No MMP Teachers)

<table>
<thead>
<tr>
<th>Teachers</th>
<th>Class Assessment Mean</th>
<th>Grade 1 Assessment Mean (No MMP Teachers)</th>
<th>Delta</th>
</tr>
</thead>
<tbody>
<tr>
<td>Susan</td>
<td>93.3</td>
<td>92.3</td>
<td>+1.0</td>
</tr>
<tr>
<td>Sandra</td>
<td>94.8</td>
<td>92.3</td>
<td>+2.5</td>
</tr>
<tr>
<td>Mary</td>
<td>92.3</td>
<td>92.3</td>
<td>0</td>
</tr>
<tr>
<td>4th MMP Teacher</td>
<td>93.4</td>
<td>92.3</td>
<td>+1.1</td>
</tr>
</tbody>
</table>

The mean scores for the students on the common end-of-the-year assessment for the three teachers in the study were higher or the same as the student mean score of all veteran first grade teachers.

**Grade 4 Results**

During the year of the study, there were twenty fourth grade teachers in the district, three of whom participated in the Math Mentor Program. The mean of student
scores on the end-of-the-year common assessment for all fourth grade teachers was 79.0 with a range of 28.5 and a standard deviation of 1.4. The median score was 79.3.

When the student assessment scores for the three teachers who participated in the Math Mentor Program were removed from the sample, the new student mean for all fourth grade veteran teachers was 80.4 with a range of 17.1 and a standard deviation of 1.2.

Table 8 displays the student mean score of the teacher in the study as well as the other two MMP fourth grade teachers as compared to the student mean for all veteran fourth grade teachers.

Table 8: Comparison of Assessment Means of MMR Study Teachers to Grade 4 Cohort (No MMP Teachers)

<table>
<thead>
<tr>
<th>Teachers</th>
<th>Class Assessment Mean</th>
<th>Grade 4 Assessment Mean (No MMP Teachers)</th>
<th>Delta</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barbara</td>
<td>61.7</td>
<td>80.4</td>
<td>-18.7</td>
</tr>
<tr>
<td>Teacher 1 (MMP)</td>
<td>74.3</td>
<td>80.4</td>
<td>-6.1</td>
</tr>
<tr>
<td>Teacher 2 (MMP)</td>
<td>76.1</td>
<td>80.4</td>
<td>-4.3</td>
</tr>
</tbody>
</table>

The students of the teacher who participated in the study performed poorly on the end-of-the-year assessment as compared to her veteran colleagues in the fourth grade. The scores for the other two MMP teachers were also outside of the range of one standard
deviation from the mean (78.8 to 82.0). The teacher in the study had the lowest student mean score in the grade.

**Grade 5 Results**

During the year of the study, there were seventeen fifth grade teachers, four of whom participated in the Math Mentor Program. The mean of the student scores for all fifth grade teachers who completed their data entry (16 teachers) was 77.3 with a range of 38.1 and a standard deviation of 2.5. The median score was 79.7. The range for the grade was particularly large given an outlier score of 50.7 for a class taught by a long-time veteran teacher.

When the student assessment scores for the two teachers who participated in the study as well as the other two MMP teachers were removed from the total sample, the new student mean for veteran teachers was 76.5 with a range of 38.1 and a standard deviation of 3.1.

Table 9 below displays the student means of the two teachers who participated in the study as well as the other two MMP teachers as compared to the student mean for all fifth grade veteran teachers.
Table 9  Comparison of Assessment Means of MMR Study Teachers to Grade 5 Cohort (No MMP Teachers)

<table>
<thead>
<tr>
<th>Teachers</th>
<th>Class Assessment Mean</th>
<th>Grade 4 Assessment Mean (No MMP Teachers)</th>
<th>Delta</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carolyn</td>
<td>88.8</td>
<td>76.5</td>
<td>+12.3</td>
</tr>
<tr>
<td>Jane</td>
<td>69.9</td>
<td>76.5</td>
<td>-6.6</td>
</tr>
<tr>
<td>Teacher 1 (MMP)</td>
<td>84.8</td>
<td>76.5</td>
<td>+8.3</td>
</tr>
<tr>
<td>Teacher 2 (MMP)</td>
<td>74.9</td>
<td>76.5</td>
<td>-1.6</td>
</tr>
</tbody>
</table>

The students of the two teachers in the study had a mixed performance on the end-of-the-year assessment as compared to their veteran colleagues in the fifth grade who had taught the mathematics curriculum for at least two years. Students of one of the teachers (Carolyn) in the study had one of the strongest performances in the grade. The student mean of the other teacher (Jane) was more than one standard deviation below the student mean of all the veteran fifth grade teachers.

VII. Other Significant Findings

There was one unexpected finding from the study that did not relate directly to the two research questions, but had implications for the future organization of the Math Mentor Program. The issue was program structure and how the change in structure positively improved the experience of the first grade teachers in the program.
The design of the Math Mentor Program requires that new and new-to-their grade level teachers visit their mentor’s classroom six times during the school year to observe the mentor teach a mathematics lesson. The researcher/designer of the program felt that new teachers would feel too vulnerable in their first year of teaching to want peers to observe them teaching a lesson. This view was shared by many of the mentors as well. However, after several observations in their mentor’s classroom, the first grade teachers decided to rotate among their own classrooms to observe each other teach a lesson. Their mentor participated in the new plan, acting as facilitator. All of the teachers reported that it was a very positive and enlightening experience. They reported learning a great deal about their own students from observing colleagues work with them as well as from the post-observation discussions.

**VIII. Summary of Findings**

The key findings of this study will be discussed through the framework of the two research questions and the themes represented in the sub-questions. The majority, if not all, of the teachers in the study communicated through their journal writing, interviews and questionnaire responses great consensus on each major finding.

*Research Question 1 - How did the Math Mentoring Program affect participating teachers’ perception of their ability to teach the mathematics curriculum, Investigations Into Number, Data and Space?*
**Math Content Knowledge**

While all of the teachers felt they had improved their mathematics content knowledge through their participation in the Math Mentor Program, fourth and fifth grade teachers felt the improvement most keenly. The first grade teachers experienced their improved content knowledge as an expansion of their understanding of how to present an already known concept multiple ways. While intermediate grade teachers also expressed their appreciation for learning multiple approaches to presenting a concept, they also identified new mathematical knowledge learned through the program. In general, however, teachers, when describing their new mathematical understandings, did not separate the concept from the pedagogy of teaching the concept.

**Math Pedagogical Knowledge**

Every teacher identified “questioning” as the pedagogical skill that they understood better and were able to implement in their classrooms from observing their mentor model questioning techniques. First grade teachers felt that they improved their ability to question students by also observing each other work with students. Regardless of grade level, all teachers learned how to ask probing questions to elicit student thinking, stimulate discussions, and scaffold instruction.

Another major finding was that teachers learned methods to differentiate instruction in their classrooms, which they felt were applicable and helpful. While they reported that their skills in being able to differentiate instruction improved, this remained an area identified for more professional development.
The majority of teachers reported that they understood better the need to help their students build a mathematics vocabulary. They also learned some pedagogical strategies to help students expand their working mathematical vocabulary.

Teachers reported that they learned about the importance of time (need to allow more time) in structuring a lesson and waiting for student answers to questions.

**Confidence**

Teachers perceived that they gained confidence to teach the mathematics curriculum due to several factors, but most importantly: (1) their improved ability to question students after observing their mentor teacher teach a mathematics lesson modeling good questioning skills; (2) the support and security they gained from both their mentor and cohort group. By having the opportunity to share problems with their cohort group during mentor meetings, they gained pedagogical and organizational skills to run a more effective classroom.

**Student Achievement**

The effect of the Math Mentor Program on student achievement was somewhat mixed given the results of the common grade-level, end-of-year mathematics assessments. One of the underlying goals of the program was to provide sufficient support for new teachers so that their students would perform at the same or nearly the same level of achievement as the students of their more experienced colleagues.
The students of fifth and first grade teachers in the study with the exception of one teacher equaled or exceeded the performance of teachers with two or more years experience teaching the mathematics curriculum.

The students of the fourth grade teacher scored below the grade-level mean and more than one standard deviation below the student mean of veteran fourth grade teachers.

**Classroom Practice**

The benefit of attending monthly scheduled mentor meetings provided the new teachers with organizational and instructional ideas, which not only benefited their mathematics instruction but improved their instructional practice in other subject areas. Teachers also expanded their behavior management repertoire.

**Research Question 2 - How did the various components of the Math Mentoring Program contribute to new teachers’ perception of their improved content knowledge, pedagogical strategies, confidence, and classroom practices?**

The two most cited aspects of the Math Mentor Program that were identified as significantly affecting improved content knowledge, pedagogical strategies, confidence, and classroom practice were: (1) observations of the mentor teacher teaching a mathematics lesson; and, (2) group discussions with their grade-level cohort of new teachers at the mentor meetings.
IX. Conclusion

The data presented in this chapter will be used to discuss the research questions in Chapter 5. The following chapter will present a discussion of the data in light of the research literature discussed in Chapter 2. In addition, the researcher will discuss in the next chapter the implications of the study on leadership practices, applications beyond the district, limitations of the study, and suggestions for future research.
CHAPTER V
SUMMARY AND RESULTS

I. Introduction

This chapter begins with a review of the research questions, sub-questions and a summary of the findings of with respect to the questions. This review is followed by a discussion of the findings as they relate to relevant literature presented in Chapter II. The chapter then reviews the implications for practice and policy. Following this review the researcher discusses the leadership lessons learned during the study. Finally the chapter discusses, the limitations of the study and questions for further investigation that are suggested by the findings of this study.

The outline of sections for this chapter is:

1. Introduction
2. Research Questions and Summary of Findings
3. Discussion of Findings
4. Implications for Practice and Policy
5. Leadership Lessons
6. Limitations of the Study
7. Implications for Further Research
8. Conclusion
II. Research Questions and Summary of Findings

The research questions addressed in this study were:

1. How did the Math Mentoring Program affect participating teachers’ perception of their ability to teach the mathematics curriculum, *Investigations Into Number, Data and Space*?
   a) What math content did they learn?
   b) What math pedagogy did they learn?
   c) What effect did the program have on their confidence to teach mathematics?
   d) How was student achievement affected?
   e) What classroom practices were instituted or changed as a result of their participation?

2. How did the various components of the Math Mentoring Program contribute to new teachers’ perception of their improved content knowledge, pedagogical strategies, confidence, and classroom practices?
   a) What was the effect of observing a mathematics lesson taught by the mentor?
   b) What was the effect of group discussions with the cohort group and mentor?
   c) What was the effect of keeping a reflective journal?
   d) What was the effect of reading articles focused on math pedagogy?

*Research Question 1 Findings:*

The major findings relevant to the first research question are summarized below by theme, which correspond to the five sub-questions.
Math Content Knowledge

A major finding in the study was that the teachers’ expanded mathematics knowledge was inextricably linked to their motivation to improve their ability to teach mathematics, not to learning mathematics for its own sake. Teachers were interested in expanding their repertoire of methods to explain or explore a mathematics concept in order for students to learn the concept.

While all of the teachers felt they had improved their mathematics content knowledge through their participation in the Math Mentor Program, the fourth and fifth grade teachers felt the improvement more keenly. The first grade teachers experienced their improved content knowledge as an expansion of their understanding of how to teach an already known concept multiple ways. While intermediate grade teachers also expressed their appreciation for learning multiple approaches to a problem or concept, they also identified new mathematical knowledge learned through the program. In general, however, teachers when describing their new mathematical understandings did not separate the concept from the pedagogy of teaching the concept.

Math Pedagogical Knowledge

Every teacher identified “questioning” as a pedagogical skill that they understood better and were able to implement in their classrooms from observing their mentor model questioning techniques. First grade teachers felt that they improved their ability to question students by also observing each other work with students. Regardless of grade level, all teachers learned how to ask probing questions to elicit student thinking, stimulate discussions, and scaffold instruction.
Another major finding was that teachers learned methods to differentiate instruction in their classrooms, which they felt were applicable and helpful. While they reported that their skills in being able to differentiate instruction improved, this remained an area identified for more professional development.

The majority of teachers reported that they understood better the need to help their students build a mathematics vocabulary. They also learned some pedagogical strategies to help students expand their working vocabulary.

Teachers reported that they learned about the importance of time (the need to allow sufficient time) in structuring a lesson and waiting for student answers to questions.

**Confidence**

Teachers gained confidence to teach the mathematics curriculum due to several factors, but most importantly: (1) their improved ability to question students after observing their mentor teacher teach a mathematics lesson modeling good questioning skills; (2) the support and security they gained from both their mentor and cohort group. By having the opportunity to share problems with their cohort group during observation meetings, they gained pedagogical and organizational skills to run a more effective classroom.

**Student Achievement**

The effect of the Math Mentor Program on student achievement was somewhat mixed as measured by the results of the common grade-level, end-of-year mathematics
assessments. One of the underlying goals of the program was to provide sufficient support for new teachers so that their students will perform at the same or nearly the same level of achievement as the students of their more experienced colleagues. Success in achieving that goal varied among grade levels.

The students of fifth and first grade mentored teachers with one exception equaled or exceeded the performance of students of veteran teachers (i.e., two or more years experience teaching the mathematics curriculum).

The students of the fourth grade mentored teacher scored below the grade-level mean and more than one standard deviation below the mean of the grade.

*Classroom Practice*

The benefit of attending monthly scheduled mentor meetings provided the teachers with classroom practices ideas, which not only benefited their mathematics instruction but also improved their instructional practices in other subject areas. Teachers also expanded their behavior management repertoire.

*Research Question 2 Findings:*

The two most cited aspects of the Math Mentor Program that were identified as significantly affecting improved content knowledge, pedagogical strategies, confidence, and classroom practice were: (1) observations of the mentor teacher teaching a mathematics lesson; and, (2) group discussions with their grade-level cohort of new teachers at the mentor meetings.
III. Discussion of Findings

The findings from the research correspond to the literature with regards to efficacy, math content knowledge and pedagogy, effective induction programs, and adult learning in many ways. This section discusses those relationships through the lens of the two research questions and the themes identified in the sub-questions.

Research Question 1 - How did the Math Mentoring Program affect participating teachers’ perception of their ability to teach the mathematics curriculum, Investigations Into Number, Data and Space?

- What math content did they learn?
- What math pedagogy did they learn?
- What effect did the program have on their confidence to teach mathematics?
- How was student achievement affected?
- What classroom practices were instituted or changed as a result of their participation?

Math Content Learned

One of the key findings in the study with regard to math content knowledge learned is that the teachers felt that their knowledge of mathematics improved as a result of their participation in the Math Mentor Program. The extent of knowledge gained varied by grade-level and by the type of knowledge gained. Teachers in the intermediate grades felt that they learned both new concepts in mathematics as well as alternate ways to present mathematical ideas. First grade teachers, by comparison, talked about their new mathematical knowledge only in terms of learning new methodologies to teach a
particular concept that they already knew. Ma (1999) emphasized the importance of teachers being able to understand, elicit, and demonstrate multiple approaches to a problem.

Teachers were interested in deepening their mathematics knowledge to the extent that their new understandings improved their ability to teach mathematics, which supports the view of many theorists and researchers that at the elementary level content knowledge cannot be separated from math pedagogy and knowledge of how students learn mathematics (Ball, 1996; Ball & Cohen, 1999; Ma, 1999; Ball; Ma, 1999). While a few teachers expressed a new appreciation for mathematics and enthusiasm for teaching mathematics, their comments were almost always made within the context of how their new knowledge would improve their instructional practice.

Liping Ma (1999) maintains that to be an effective elementary mathematics teacher, content knowledge cannot be separated from knowledge of math pedagogy and knowledge of how students learn mathematics. Ma describes effective teacher training in mathematics as teachers acquiring a “profound understanding of fundamental mathematics” (PUFM). A PUFM teacher is “not only aware of the conceptual structure and basic attitudes of mathematics inherent in elementary mathematics, but is able to teach them to students” (p.xxiv). Both Deborah Ball and Liping Ma agree that subject matter knowledge and pedagogical knowledge are inextricably linked for elementary teachers.

While content and pedagogical knowledge are linked, one cannot teach mathematics without knowing it. Content knowledge at any level, but particularly at the
elementary level, is not a sufficient condition for being an effective mathematics teacher (Ball, 2008, 2006; Ball & Cohen, 1996; Shulman, 1986; Grimmet & MacKinnon, 1992: Ma, 1999). The teachers’ perception of the linkage between content knowledge and pedagogy is supported by the major theorists and researchers in the field of mathematics education. Theorists assert that the goal of teacher education and professional development programs should not be to produce teachers who know mathematics, but rather to support student learning in mathematics (Hill, Rowan, & Ball, 2005; Ball, 2008; Ma, 1999).

Ball (2003) asserts that the mathematics knowledge needed for teaching differs from the mathematics needed in other mathematically intensive fields. Teachers need to know sufficient mathematics to interpret someone’s error, represent ideas in multiple forms, provide alternate explanations, and define terminologies (Ball, 2003, p.6). Teachers in the Math Mentor Program reported a gain in their ability in all four areas.

**Math Pedagogy Learned**

All of the teachers in the Math Mentor Program reported that they improved their ability to question students in order to elicit their students’ understanding and reasoning. Theorists and researchers have identified many skills as exemplary pedagogical practices for teaching mathematics. Among the most important is the ability of a teacher to probe student ideas as opposed to assuming that she knows what students mean (Ball, 2008, 2006; Ma, 1999; Ball & Cohen, 1996; NCTM, 1991). Ball (2008) asserts that effective mathematics teachers need to provoke disequilibrium and error instead of correcting and
smoothing over mistakes; effective teachers listen, watch, and help students “do” instead of telling, showing, and “doing for” students. Developing the art of effective “questioning” is an essential skill that is necessary to be an effective mathematics teacher as Ball describes. The teachers felt that their ability to question their own students improved by being able to observe their mentor question students. They learned the importance of listening carefully to and waiting for student answers.

Researchers (Good & Brophy, 1987; Leinhardt & Smith, 1985; Shulman, 1986) have found that first year teachers frequently do not demonstrate the flexibility to adjust their instruction to the needs of their students often because they have not uncovered misconceptions or confusions by questioning their students to probe their thinking. Most of the teachers expressed concern that they were not able to adjust their instruction to the needs of their struggling students in part because they were unable to ask the right questions to find out what they did not know.

Raymond (1997) found in a ten-month study of six elementary teachers regarding their beliefs and mathematics teaching practices that there were three significant influences on mathematics teaching practices - mathematics beliefs, the classroom situation, and current teaching practices. Teachers in the Math Mentor Program reported some changes in their mathematical beliefs and knowledge, but the most significant change was in their teaching practice. They incorporated more “questioning” to probe student thinking and introduced activities to differentiate instruction.

The teachers also reported that they learned methodologies to differentiate instruction and present concepts in multiple formats. Leading mathematics educators and
researchers have noted the importance of teachers being able to present mathematical ideas in multiple ways and to unpack ideas to make them accessible to a range of learners (Ball, 2008, 2006; Ma, 1999; Ball & Cohen, 1996; Hill & Ball, 2004).

By observing their mentor, the teachers reported learning the importance of helping their students develop a mathematics vocabulary, which has been identified by Ball (2003) as one of the five important practices for effective mathematics teaching.

**Confidence**

The teachers in the study reported that they felt more confident to teach mathematics due to their participation in the program, in part because they felt supported by their mentor and fellow teachers. They also felt more confident because they experienced success in teaching lessons in their own class after observing their mentor teach the same or similar lesson. Confidence and self-efficacy in teaching mathematics are closely related, both are affected by a person’s belief in her capability to understand the mathematics she is teaching and her perceived success in promoting student learning (Wolfolk, Hoy & Spero, 2005).

The importance of a teacher’s sense of self-efficacy was identified thirty years ago by a study by the RAND corporation as “one of the few teacher characteristics related to student achievement” (Armor et al, 1976). Allinder’s (1995) study of special education teachers confirmed that teachers with both high teaching and personal efficacy had a better chance of improving students’ achievement (end-of-year goals) than teachers with low teaching and personal efficacy scores. Ashton and Webb’s (1986) study of high
school mathematics teachers indicated that a positive correlation existed between a teacher’s beliefs about her instructional efficacy and student achievement.

The teachers’ increase in confidence (perception of efficacy in teaching a mathematics lesson) corresponds to Bandura’s (1997) theory of self-efficacy, which can be developed through four types of experiences: mastery, vicarious, social/verbal persuasion, and psychological/emotional arousal. A mastery experience occurs when a teacher is able to demonstrate to herself that she is a competent instructor. The success the teachers experienced by teaching a modeled lesson is an example of a mastery experience. Developing and expanding content and pedagogical knowledge is also considered a mastery experience because of its effect on efficacy and competence.

A second source for increasing efficacy (Bandura, 1997) is vicarious experiences, which are experiences of someone else modeling a skill. Hoy and Spero (2005) contend that the stronger the identification with the person modeling the skill, the greater the effect on the observer and their sense of efficacy. All of the teachers in the study were very complimentary of their mentor’s teaching competence and felt that they had benefited significantly from observing her teach and were better teachers from the experience.

Since the program spanned ten months, the length of the program may have enhanced the effect. In another professional development program, Ross (1994) found that teaching efficacy increased after eight months of training on cooperative learning, particularly if the teacher implemented the change in her classroom successfully. Similarly, in this study, all of the teachers perceived improved confidence to teach
mathematics after ten months of training in the Math Mentor Program by implementing newly learned instructional pedagogies and classroom practices into their classrooms.

A couple of the teachers in the study expressed some anxiety about teaching the mathematics curriculum because they were being asked to teach in a way different from how they learned mathematics while in school themselves. As young students, a few of the teachers did not like math, but as adults had begun to appreciate and enjoy math due to their teacher education programs and their experience in the Math Mentor Program. The teachers (including those with a strong mathematics background) were quick to add, however, that knowing and liking mathematics was different than having to teach it using a constructivist approach, which is the orientation of the district’s mathematics curriculum.

The importance of past school experience was found by researchers (Raymond, 1997; Cornell, 1999) to be a significant influence on mathematical beliefs, which is the most significant influence on mathematics teaching practices. Bursal and Paznokas (2006) found in a study of sixty-five elementary teachers given the Revised-Mathematics Anxiety Survey (R-MANX) along with questions from the Mathematics Teaching Efficacy Beliefs Instrument and the Science Teaching Efficacy Beliefs Instrument that there was a negative correlation between preservice teachers mathematics anxiety and confidence teaching mathematics. Those with the highest mathematics anxiety scores believed “that they will not be able to teach mathematics effectively” (Bursal & Paznokas, 2006, p.177).
Some of the teachers reported that their attitude about mathematics changed due to their adult experiences, which supports researchers’ (Darling-Hammond, 2000; Huinker & Madison, 1997) finding that teachers’ attitude about mathematics and teaching mathematics can be influenced by their participation in teacher education programs – the more preparation, the more confident teachers are teaching mathematics. In another study, Hart (2002) found that the alignment of the mathematics method course to NCTM Standards correlated positively with preservice teachers’ changed beliefs about mathematics. The limitation, however, of these studies is that only preservice teachers were included in the research.

Hoy and Spero (2005) measured self-efficacy of teachers at three different times - before they started a teacher education program, while student teaching, and after their first year of teaching. “Results indicated significant increases in efficacy during student teaching, but significant declines during the first year of teaching. Changes in efficacy during the first year of teaching were related to the level of support received” (p.355).

Trujillo and Hadfield (1999) concluded from their study of fifty preservice teachers that math anxiety can be reduced in teachers by providing mathematics methods courses and professional development opportunities that deliver “cutting edge lessons in mathematics for elementary school children” (p.10).

Three of the six teachers (all first grade teachers) in this study did not take any mathematics methods courses in their undergraduate or graduate programs. While all of the teachers to some extent expressed some anxiety about teaching the curriculum, the first grade teachers expressed this concern more frequently. Levine (1996) found that
mathematics courses improved not only competence but helped reduce anxiety. While two of the first grade teachers had taught mathematics for two years in another out-of-district school, the Math Mentor Program was their first experience in any type of methods training. Bandura (1997), as well as Hoy and Spero (2005), found that the level of support a teacher had in her first year of teaching correlated positively with self-efficacy, which correlates positively with student achievement.

**Student Achievement**

The goal of the Math Mentor Program was to support new teachers in learning the mathematics curriculum and the constructivist approach to teaching the curriculum for the purpose of increasing student performance in mathematics. In this study, student achievement was measured by the scores of students on the common end-of-year, grade-level assessments, which were developed by teachers in the district. The desired result was that students taught by teachers in the program would score at the same level as teachers who had taught the curriculum for at least two years or, at least, within one standard deviation of the veteran grade level mean. This result was true for the students of the first and fifth grade teachers, but not for the fourth grade teacher.

The reasons for this discrepancy are unclear. One reason could be the complexity and breadth of the learning standards at fourth grade, which are challenging even for veteran teachers to teach effectively in the span of one school year.

Given that the students of all three new fourth grade teachers did not perform as well as students of veteran teachers, another reason may be the curriculum materials used
in the fourth grade. One major difference between the fourth grade mathematics
curriculum and that of the other elementary grades is that the fourth grade relies less on
TERC’s *Investigations Into Number, Data and Space* for resource materials. The first
edition of *Investigations*, which is used in the district, does not align well with the state
standards at certain grades, particularly fourth grade. Over several years preceding the
study, the fourth grade curriculum was aligned to the state standards by teachers in the
district, not TERC authors. Resource materials were gathered from many sources
including *Investigations*. The fourth grade curriculum is organized into two-binders of
lessons that correspond with the district-developed curriculum pacing chart. The
expectation is that teachers teach the curriculum using an investigative approach.
Teachers in the fourth grade, however, do not have the same number of *Investigation*
resource books that explain lessons in detail as do other grades, which presents a greater
challenge for new fourth grade teachers. Therefore, more support may be needed for new
teachers at this grade than for teachers in the other grades. The results of this study may
also indicate that the grade to begin the implementation of the new edition of
*Investigations* (which is aligned with the state standards) is fourth grade.

Additional explanations for the poorer student performance of fourth grade
teachers in the Math Mentor Program as compared to veteran colleagues could include
the academic background of the teachers, the level to which they implemented modeled
teaching strategies in their classroom, the academic needs of the students in their
classroom, the level of support they received in their school or their perceived
mathematical efficacy, which may have improved during the school year but not to the same extent as new teachers in other grades.

A concern for the researcher with respect to the performance of students on the end-of-year assessments was that the overall performance of students decreased from first grade to fifth grade. The assessments were created by district teachers with the intent of designing a rigorous assessment to evaluate which mathematics skills and concepts were widely mastered and which content areas may need to be emphasized more the following school year. The lower scores in fourth and fifth grade as compared to first grade reflect the increased difficulty of the curriculum at the upper grades. Nonetheless, many scores below 80% are a cause for concern as are low scores for any particular sub-group, including gender.

Classroom Practice

The teachers reported that their experience in the Math Mentor Program had other positive effects on their classroom practice, including helping them make connections between mathematics and other subject areas. The NCTM reform efforts included new components to traditional mathematics instruction, including problem-solving, mathematical communication, cooperative learning activities, multi-representational based instruction (including increased use of manipulatives), mathematical connections, and multiple types of assessments (including student explanations). These NCTM recommendations have encouraged teachers to develop more student-centered teaching strategies where teachers probe student thinking and design lessons that foster student
investment. These teaching strategies can be generalized to other subject areas. Teachers in the study reported using group organizational strategies learned from their mentor for other subjects. They also learned to make connections between mathematics and other subjects, most notably literature. The NCTM reform movement also encouraged teachers to embed mathematics in activities to provide a concrete perspective for abstract ideas and to make mathematical connections throughout the school day.

An interesting study the district undertook which relates to this issue is the relationship between student achievement and departmentalization in the fifth grade. Two schools in the district departmentalize mathematics instruction while in the other schools, teachers teach mathematics in self-contained traditional elementary classrooms. Teachers self-select to teach mathematics in departmentalized grades. These teachers generally have a strong interest and background in mathematics.

Students in the self-contained classrooms, however, have scored better in mathematics on the annual state assessment (MCAS) for three years in a row than the students in the departmentalized classrooms. One theory regarding this counter-intuitive discrepancy is that teachers in the self-contained classrooms have the opportunity to make mathematical connections throughout the day. The district plans to do a longitudinal study on student achievement in departmentalized classes as compared to traditional classrooms, looking at other variables such as teacher experience and preparation.

Among the goals that are identified as necessary for a twenty-first century education is fostering the ability of students to communicate well in multiple modalities,
work well in groups, think critically, and be creative problem solvers. The teachers reported that, as a result of their participation in the Math Mentor Program, they learned how to organize their students into productive groups and elicit through questioning student explanations. They also learned ways to help students make connections between mathematics and other subjects, particularly literature.

**Research Question 2** - *How did the various components of the Math Mentoring Program contribute to new teachers’ perception of their improved content knowledge, pedagogical strategies, confidence, and classroom practices?*

There were four components of the Math Mentor Program: observations of mathematics lessons in the mentor’s classroom; group discussions pre and post observations; reflective journal keeping; and, relevant and informative math articles. Of the four components, the teachers identified the first two components, observations and group discussions, as being the most significant influences on their instructional practice.

Timmerman (2004) found that professional development opportunities that provide teachers with an opportunity to improve their pedagogical skills characterize an effective induction program. Loucks-Horseley et al. (1996) outlined the components of effective professional development. Among the components include opportunities both to observe effective classroom learning and teaching of mathematics and to build learning communities of mathematics teachers. Ball and Cohen (1999) describe these components of effective professional development as “learning in practice”, which is an active form of job-embedded learning. Sparks and Hirsh (1997) report that the traditional form of
workshop-type professional development has fallen out of favor with school districts because it has not proven to produce long-lasting results in the classroom. Alternatively, what is suggested is that professional development be job-embedded. “Job-embedded learning… links learning to the immediate and real-life problems faced by teachers and administrators which occurs in response to challenges currently being faced by the learner and that allows for immediate application, experimentation, and adaptation on the job” (p.52).

The Math Mentor Program provided teachers with job-embedded professional development in the form of multiple opportunities to observe highly experienced and effective teachers teach a mathematics lesson, which they were able to replicate in their own classrooms. Teachers also developed a community of peers to discuss mathematics pedagogy and classroom challenges.

The first grade teachers expanded their observations to observing each other teach. Timmerman (2004) found that observing peers teach and engage with students was a successful intervention to help teachers understand the mathematical knowledge needed to be taught for mathematical proficiency.

Malcolm Knowles (1989), a leading researcher in adult education, states that adults want to apply what they learn in their personal and professional lives. Therefore, they need to learn why they are learning something before they learn it. With respect to teaching, the why of what new teachers need to learn is fairly clear in the context of the expectations and standards of student learning and achievement for which they are held accountable.
Oji (1980) described the four characteristics of effective teacher in-service learning based on adult learning theory: (1) concrete experiences need to be transferable to their teaching; (2) available resources for supervision and advising; (3) encouragement and opportunities to assume new and complex roles; and, (4) support and feedback when implementing new programs and strategies. The design of the Math Mentor Program implemented all four components.

With respect to teacher retention, successful induction programs have been successful in reducing attrition rates of new teachers (Feiman-Nemser, 2005; Strong, 2005; Ingersoll, 2001). It is too early to tell what effect the Math Mentor Program will have on elementary teacher retention over several years. While two of the six teachers interviewed in the study left the district after their first year of teaching, the other thirteen teachers in the Math Mentor Program continued to teach in the district. One of the two teachers who left did so because her spouse relocated to another state for a job. She planned to seek a teaching job in her new home. The other teacher resigned and her current teaching status is unknown.

What can be learned from the literature on self-efficacy, adult learning, induction programs and content-based professional development is that it is important for participants to improve their own sense of self-efficacy and knowledge of the discipline through learning activities that are centered in the classroom. Feiman-Nemser (2001) concurs:
[New teachers need] a compelling vision of good teaching and a beginning repertoire of approaches to curriculum, instruction, and assessment consistent with that vision. A major task of induction is helping new teachers enact these approaches purposefully with their students by developing the necessary understanding and flexibility of response (p.1029).

**IV. Implications for Practice and Policy**

V.

The value of any educational research is directly related to the benefit realized by students. Most, if not all, school districts in the country are struggling with how to improve the mathematics performance of their students on state assessments because of the proficiency mandates of the 2001 *No Child Left Behind* Act. School systems face the double pressure of needing to meet ever-increasing proficiency targets while at the same time experiencing significant changes annually in their teaching staff due to retirements and general attrition of teachers from the profession. It is imperative that new teachers be able to teach mathematics at a high level of competence in order for schools to meet their Adequate Yearly Progress (AYP). The consequences of not making AYP are significant, both politically and financially.

Nationwide, it is estimated that nearly forty to fifty percent of new teachers leave the profession within the first five years (Ingersoll & Kralik, 2004), which costs districts financially and compromises the achievement of students. Research has shown that there is a positive effect on the achievement of students who are taught by a teacher with more than three years of teaching experience (Murnane & Phillips, 1981). Combined with the
increased rate (nineteen percent over the previous five years) of retirements in Massachusetts, there is a need in districts to provide mentoring/induction programs that support teachers in their early years of teaching to reduce the rate of attrition.

Kardos and Johnson (2007) found in their study of 486 first-year and second-year full-time K-12 teachers from four states that the organizational structures and professional culture of schools contributed to teacher retention. Professional cultures are influenced by “mentoring, classroom observations, teacher meetings, collaboration, and professional development” (p.2). Kardos and Johnson’s survey results reveal that many of the new teachers felt that they were expected to be independent and an expert from the start. Nearly half the new teachers in the sample reported that they plan lessons alone and teach alone even though “teaching is too complicated an art and craft to be mastered in isolation”(p.9). The frustrations associated with new teachers’ early career failures are partially responsible for their turnover, whether they transfer to another school or leave teaching altogether” (p. 9). Smith and Ingersoll (2003) found that mentoring/induction programs, which included collaboration and common planning time, considerably improved retention.

Research has demonstrated a clear linkage between the content and pedagogical knowledge of teachers and student performance. Given this relationship, how can school districts improve the teaching skills of teachers, particularly new teachers, in mathematics that is effective? How can school districts institutionalize professional development that is essential for common expectations and consistency?
Current research (Reeves, 2008; Sparks & Hirsh, 1997) supports the finding that job-embedded professional development that includes teachers observing other teachers is one of the most effective professional development opportunities districts can offer teachers. Given the cost of out-of-district conferences and outside speakers, the cost associated with an in-district observation program involving just the cost of substitutes and, possibly, stipends for mentor teachers compares favorably.

Reeves (2008) found in his study of 81 teams of teachers in the Clark County School District in Clark County Nevada:

Teachers not only exert significant influence on the performance of students, but they also exert significant influence on the performance of other teachers and school leaders. Overall, the educators in this study reported that they were more likely to be influenced by the professional practices and action research of their peers than they were to be influenced by journal articles or undergraduate or graduate courses….The most important finding of the study….is that direct observation of the professional practices of teachers by teachers must become the new foundation of professional development (p.3).

The findings from this study are consistent with what Reeves (2008) found in his study of Clark County teachers. The most influential aspect of the Math Mentor Program on practice was the opportunity for new teachers to observe their mentor teach.
The teachers who participated in the Math Mentor Program gained the pedagogical understandings and skills to be at least at a beginning level of competency necessary to teach the mathematics curriculum in a manner consistent with the district’s expectations and with the reforms proposed by NCTM that are viewed as essential for effective mathematics instruction in the 21st century. With the exception of one grade, all the students of new teachers performed at a level on the end-of-year assessment that was consistent with the more experienced teachers in their grade.

While teachers felt conflicted about being out of their classrooms six mornings or afternoons over the course of the school year, they uniformly felt, after the fact, that the sacrifice was worth it given what they gained from the experience.

Should another district be interested in developing a similar mentoring program, there are a number of issues to address. The most important is the “buy-in” from all of the elementary principals, which is essential to its success. Principals need to recognize the long-term benefit to their school from the absence of teachers from class and be prepared to deal with the inevitable inconveniences associated with a district-wide program that requires everyone involved to be flexible and willing to pitch-in should a substitute not be available to cover a teacher’s class or an observation date need to be rescheduled.

Another important consideration is that mentors need to be carefully chosen and then trained so that the pedagogical practices are consistent across all grades. To the extent possible, each school should be represented in the mentor group. The positive benefit to the school district, in addition to the professional development available to new
teachers, is the creation of teacher leadership positions that are non-administrative in scope, but offer positive leadership within schools for mathematics education. Often veteran teachers are ready to take on leadership roles but do not want to leave teaching to be a principal. Silns and Mulford (2002) have shown that student achievement is more likely to improve in schools where leadership is distributed throughout the school. The report of the Task Force on Teacher Leadership (2001) strongly recommends that teacher leadership should be fostered in schools, which will result in a more professional atmosphere in schools, which in turn, will promote an environment of continuous improvement that is essential for meeting the increasingly complex challenges facing students today. Additionally, schools where teachers are valued as experts are better prepared to attract and retain quality teachers.

Elmore (2000) believes the success of students is contingent upon breaking down the “privacy of practice” in schools and developing a culture of collegiality. He says that distributed leadership “posits a model in which instructional practice is a collective good – a common concern of the whole institution – as well as a private and individual concern” (p.24).

While the focus of this study was the effect of the Math Mentor Program on the performance and confidence of new teachers, the implementation of the program has had a wider benefit to the district than just the training of new teachers in the pedagogy of teaching mathematics.

An implication for district hiring policy that emerged through the literature review and data analysis in the study is that there are two important questions to ask candidates
seeking an elementary teaching position regarding their preparation to teach mathematics: (1) Did you take a math methods course?, and (2) How many math content courses have you had as an undergraduate and graduate student? The ideal answer to the first question is “yes”, and to the second questions, “more than 2 or 3”. While there is a need for schools to hire teachers who can teach mathematics competently, preparation to teach mathematics is only one of many qualities schools need to consider when hiring elementary teachers.

V. Leadership Lessons

The researcher who was also the creator and force behind the development of the Math Mentor Program learned much about her own leadership skills and the skills needed to implement and institutionalize a district-wide program. The themes included creating urgency and “buy-in”, building trust, being collaborative and open to new ideas, being attentive to and adjusting to obstacles, and giving praise.

Additionally, the researcher learned what she valued with respect to how schools and districts should be organized. She learned that her belief in distributed leadership is valuable in both elevating the practice of teachers and promoting a school culture of continuous professional growth.

The Math Mentor Program was a very new concept in professional development for the district because it was a program that was offered during the school day over an extended period of time. Historically, with few exceptions, no professional development
was offered that removed teachers from their classrooms. Professional development was only offered after school, on the professional development day, or during the summer.

The researcher needed to create a sense of urgency for a job-embedded program during the school day that required extensive cooperation among schools, teachers, principals, and was moderately costly.

The factors, which influenced the researcher to propose the program, were the rate of turnover among the elementary teachers and the gap in mathematics performance among the elementary schools. For several years prior to the program implementation, the district hired between 15 and 30 new elementary every year due to retirements, mobility, and non-renews. Nearly half of the elementary teachers were new to the district within three years of the start of the program. Most of the teachers in the district had never participated in the initial professional development that was provided to all the elementary teachers when the mathematics curriculum was implemented.

While the gap in mathematics performance on MCAS had been narrowing among the elementary schools, during the three years prior to the start of the program the narrowing process had slowed down. The mathematics scores at many of the elementary schools were improving but not at a rate expected after aligning the curriculum with the state curriculum standards, developing curriculum pacing charts, and instituting common unit and end-of-the-year assessments, the results of which were shared among colleagues at the building level. The need to narrow the gap among the elementary schools was seen by the researcher as a moral imperative. All students should have the same opportunity to learn, which is contraindicated by gaps in performance. Starratt (2003) writes, “The
logic of test-based accountability says that schools have to be relentlessly inventive in finding ways to help students learn…”(p.300). There are many factors that affect student learning, but one of the most important is teacher quality, which can be influenced by strategically designed professional development.

The combination of factors created the urgency for developing a professional development program that would help support new teachers in learning the mathematics curriculum and teaching it with a level of competence necessary to maintain the positive trajectory of improvement required by law. The challenge to the researcher was communicating this urgency to central office administrators and the elementary principals and convincing them of the merits of the program, which would need everyone’s cooperation to be successful. The researcher learned the value of persistence and steadiness of vision.

Starratt (2003) writes, “Educational leaders must be morally responsible, not only in preventing and alleviating harm but also in a proactive sense of who the leader is, what the leader is responsible as, whom the leader is responsible to, and what the leader is responsible for” (p.49). As a leader in the district, the researcher had the responsibility to work with others to remedy a problem that affected the learning of hundreds of students. As an authentic leader, the researcher according to Starratt (2003) must have “a clear eye on promoting the learning of students, seeking ways that administrative decisions can further that work” (p. 79).

Building and maintaining trust with the principals and mentors was a central concern throughout the project. The issue of trust with the principals centered on

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reciprocal obligations that involved communication, timeliness, and sensitivity to the needs of each building balanced with the need for central organization. Sergiovanni (2005) writes that relationships between organizations and people be based on trust; “trust is the tie that binds roles and allows for the creation of role sets that embody reciprocal obligations” (p.119).

Trust was built with mentors by recognizing their expertise and encouraging them to be important contributors in the development and on-going evaluation of the program.

It is a fallacy to believe that the implementation and success of any program is due to the work of just one individual. Rather, it is the fruit of the collaborative efforts of many people. The Math Mentor Program was no exception. The researcher learned, once again in this project, the value of taking an idea from “mine” to “our”. The resulting program benefited from the collaborative ideas of many individuals. One example was the development of the second year phase of the program, which involved giving each grade level cohort the opportunity to observe in each other’s classroom with their mentor participating with them. Another example of the collaborative work of the researcher and mentors was the development of the end-of-year questionnaire and reflective journal prompts.

There were numerous obstacles along the path, most at the operational level of the plan. Observation sessions for each grade had to be scheduled to minimize the number of substitutes that were needed for coverage. To the extent possible grade levels were paired so that one grade met in the morning and another in the afternoon in order to share substitutes. Other considerations in planning at each building were the lunch schedules
field trips, assemblies and concerts, MCAS, and parent conferences. Last minute mentor illnesses required the need for alternative plans. The researcher was involved at all levels of the planning and implementation, which she felt was an essential responsibility of the leader. She was aware that if too much frustration was felt with the operational side of the program, the call to eliminate the program the following year would surface.

The researcher took every opportunity to praise the mentors for their willingness to share their expertise by inviting mentees into their classroom to observe them teach. The researcher recognized that it took a lot of courage for the mentors to make themselves vulnerable to the judgments of other teachers. Complimentary comments of mentees were shared with the mentors. The researcher/leader recognized the importance of an affirming presence, which Starratt (2003) defined as an “attitude of unconditional regard for the person or persons you are working with. It means not only holding them interiorly in high regard but also explicitly expressing your regard in a variety of ways” (p.91).

VI. Limitations of the Study

There were several limitations, which may compromise the internal validity of this study. First, the researcher acknowledges a potential bias as the person who conceptually designed the Math Mentor Program, selected the mentors and designed most of the data gathering instruments, which could potentially undermine the validity, as well as, reliability of the study. In this role the influence of the researcher cannot be
eliminated. However, Merriam (1998) writes, “Validity and reliability are concerns that can be approached through careful attention to a study’s conceptualization and the way in which the data were collected, analyzed, and interpreted, and the way in which the findings are presented” (p. 199). Merriam outlines six basic strategies to enhance internal validity, which include triangulation of data, member checks (checking data with the sources), long-term observation or repeated observations, peer examination, participatory or collaborative modes of research, and communicated researcher biases (pp. 204-205).

In this study all of the data were triangulated, meaning that the data were drawn from multiple sources to confirm findings. Throughout the study, teacher participants and mentors were conferred with regarding their experience. The researcher attended grade-level observation sessions over the course of the year, therefore, ensuring repeated observations to verify impressions.

Peer examination was accomplished by conferring with mentor colleagues and teachers throughout the study on the principle findings. Mentors were involved at the inception of the program as well as throughout its implementation, which ensures a broad-based collaboration in the study. Finally, the bias of the researcher was that the Math Mentor Program is successful in meeting its stated goals, but the researcher also wanted to know if it, in fact, was successful. The satisfaction of the other five strategies (triangulation of data, member checks and repeated observations over an extended period of time, peer examination, and collaborative modes of research) helped to minimize the potential effect of this bias.
Another limitation in the study was that the sample of six teachers was small which could affect the external validity (the generalizability) of the findings. Merriam (1998) writes that qualitative studies that provide “rich, thick descriptions” (p. 211) allow outside readers to decide for themselves if the information offered closely matches their own situation as to be useful.

The sample size could also affect the reliability of the study, the extent to which it can be replicated. However, Merriam (1998) states:

Qualitative research, however, is not conducted so that the laws of human behavior can be isolated. Rather, researchers seek to describe and explain the world as those in the world experience it. Since there are many interpretations of what is happening, there is no benchmark by which to take repeated measures and establish reliability in the traditional sense (p. 205).

Therefore, reliability in qualitative study is not a significant measure of limitation.

If this study were to be repeated with another group of teachers, the researcher would suggest using the Mathematics Self-Efficacy Scale (MSES-Revised) developed by Hackett and Betz (1989) to measure mathematics self-efficacy on problems and tasks both at the beginning of the study and at the end rather than relying on teachers to self-report their level of confidence.

This case study offers a different kind of generalizability, one that focuses on theory rather than replication in other populations. The findings in this study confirm the
research on the importance of support and mentoring for first year teachers, the importance of questioning to elicit student thinking in mathematics education, and the importance of job-embedded professional development for the adult learner.

Other factors not accounted for in the study which could influence the variability of each teacher’s responses and, thus, influence their perception of the effect of the Math Mentor Program on their practice and confidence, include their own school environment (some schools have stronger math cultures than others) and their own mathematics efficacy.

VII. Implications for Further Research

Future case studies and research could contribute additional understanding and perspectives in several areas suggested by the findings in this study.

While there has been some research on the relationship between mathematics self-efficacy and mathematic teaching self-efficacy for preservice teachers, more research is needed to know how predictive one is of the other and what interventions are most effective in improving mathematics teaching self-efficacy with classroom teachers as the focus.

In this study, effective mentoring was a major influence in supporting new teachers in improving their confidence to teach math, their content knowledge, and pedagogical skills. It would be interesting to know what the effect of being a mentor had
on the mentor’s practice, self-efficacy, and other leadership roles within the school community.

The Math Mentor Program during the year of the study evolved into a two-year induction program. In the second year, “new” teachers from the first year program at each grade level along with their mentor rotated to observe each other teach a mathematics lesson. At the end of the observation, the group met to discuss the lesson with the teacher. An extension of this study could be undertaken to examine the effect of the second year program on the instructional practice and confidence of the participating teachers.

One of the findings of this study was the importance of group discussions in helping new teachers feel supported. Because of this finding, the plan going forward is to group first and second year teachers at a grade if there is only one new teacher at a that grade. The effectiveness of this arrangement will need to be examined.

Related to student performance, an area for further study involves the performance of students in departmentalized classes as compared to students in self-contained classes. The district did an analysis of student performance on the state annual assessment (MCAS) for elementary schools that departmentalized mathematics instruction in fifth grade as compared to schools that did not departmentalize but were traditionally organized into self-contained classrooms where the teacher taught all subjects. The students in self-contained classes performed better on MCAS than those in departmentalized classes. This discrepancy needs to be studied over several years to
determine if the same pattern repeats itself. If it does, the factors that cause this outcome need to be examined.

One of the concerns expressed by several participants in the study was that they regretted being out of their class six times during the school year. A possible adjustment to the program to consider in future years is to eliminate one or two observations and substitute an after-school discussion group modeled on Critical Friends with the mentor as facilitator.

VIII. Conclusion

This study was undertaken to gain insight into the effectiveness of a Math Mentor Program for new teachers to prepare them to teach the district’s mathematics curriculum. The effectiveness of the program was examined through five themes: mathematics knowledge learned, mathematics pedagogy learned, confidence, student achievement, and classroom practice changes. The structure of the program was also examined for its most influential components on practice.

The findings of the study suggest that the Math Mentor Program was effective in helping to prepare new teachers to competently teaching the mathematics curriculum, as evidenced by their perceptions and their students’ scores on the end-of-the-year assessment. The teachers reported that the most influential aspect of the program on their practice was the opportunity to regularly observe a skilled veteran teacher teach a mathematics lesson followed in importance by discussions after the observations with their peers. These findings are consistent with recent research that indicate that the most
influential form of professional development on practice is teachers observing other
teachers

Reeves (2009) writes:

When schools embrace the strategy of using outstanding teachers to influence the
practice of their peers…and when school leaders provide sufficient administrative
support and authority, establishing the expectation that professionalism means
sharing best practices, the rewards – higher standards of professional excellence,
improved engagement by staff and students, and most of all, improved practice –
far outweigh the risks”(p.86).
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APPENDIX
After each mentor session, please reflect upon your observation using these prompting questions. Before the next month’s meeting, please share your journal with your mentor who will respond with comments. A copy of your journal should be sent to the Assistant Superintendent’s office by June 6.

From *Talking Mathematics* in Teaching Children Mathematics (Sept. ’07):

In *Introduction to Brain-Compatible Learning*, Eric Jensen states that “learning is maximized when an exchange of emotions, feelings, sharing, discussion, brain-storming, and problem solving takes place.” Elinor Perry Ross agrees with Jensen when she says in *Pathways to Thinking*, “The social nature of learning recognizes the importance of talk in the classroom.”

1. What did you learn about questioning? What questions enrich the mathematical discourse?

2. What did you learn about mathematical connections? Making connections with past knowledge?

3. When in the lesson were students asked to reason mathematically?

4. Describe rich mathematical conversations heard among or between students.

5. Describe how you incorporated ideas learned into your classroom.
MATH MENTOR PROGRAM
INITIAL SURVEY
(Will only be read by Mentor and Director of Math/Asst. Superintendent)

NAME ___________________________            GRADE ________

Years of teaching experience: _______________

Have you taught math using TERC Investigations before? ________

    If yes, which grade level(s)? __________ # of years: ___________

    If no, have you taught math using other standards based programs? _____

        The program(s): __________________________________________

How many math courses (not including methods) have you taken as an
undergraduate and, if applicable, graduate student? ________________

Have you taken a math methods course? ________________

Please circle the number which best reflects your feeling about:

    Teaching math in September.

      1 2 3 4 5 6 7 8 9 10
        not confident          very confident

    Teaching math in January.

      1 2 3 4 5 6 7 8 9 10
        not confident          very confident

What concern(s), if any, do you have about teaching math this year? What
additional support in teaching mathematics would be helpful to you?
Math Mentor Program Survey

To All Teachers Participating in the Math Mentor Program: We would appreciate your feedback on your experience in the Math Mentor Program this year. Your comments will help us adjust the program to better meet your needs and the needs of future new teachers in the district. Thank You.

Grade You Teach:  K  1  2  3  4  5  Name: ______________________
Please Circle Grade

How many meetings have you attended?  0  1  2  3  4

Years of teaching experience:  1  2  3  4  4  >5
Including current year

<table>
<thead>
<tr>
<th>My participation in the Math Mentor Program has helped me:</th>
<th>Strongly Agree</th>
<th>Somewhat Agree</th>
<th>Somewhat Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Feel more confident teaching the TERC math curriculum.</td>
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<td>7. Deepened my understanding of the math involved in observed TERC lessons.</td>
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<td>8. Diagnose and evaluate my students' understanding of math.</td>
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<td>9. Deliver math instruction to:</td>
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<tr>
<td>a. all my students</td>
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<tr>
<td>b. those who struggle with math.</td>
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<tr>
<td>10. Develop a supportive network in my cohort group of teachers.</td>
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<tr>
<td>11. Feel supported in my development as a math teacher.</td>
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<tr>
<td>7. Plan and design math lessons.</td>
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<tr>
<td>8. Improve my math knowledge.</td>
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</tr>
<tr>
<td>10. Improve mathematical discourse in my classroom.</td>
<td></td>
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</tr>
</tbody>
</table>
1. In what ways has this program met your needs?

2. In what ways did the program not meet your needs?

3. Describe three math insights and/or instructional practices that you have learned from your participation in the program and how were they implemented in your classroom?

4. If you were redesigning the Math Mentor Program for next year, what changes would you make?

5. What further professional development in mathematics do you need?
1. Through your participation in the Math Mentor Program, what mathematics did you learn?

2. In what ways has the Math Mentor Program affected your instructional practice this year? Provide 3 examples.

3. How have your beliefs about mathematics and teaching mathematics changed over the course of the year?

   Assuming changes:
   • In what ways have these changes been influenced by your participation in the Math Mentor Program?
   • Could you give a few examples of how these new insights affected your classroom instruction?
   • Are there any lessons that you will teach differently next year? Describe the changes you will make.

4. What did you learn about variations in students’ readiness to learn various units in the math curriculum? Give 3 to 4 examples.

5. What mathematics do you want to know more about after completing your first year of teaching grade __ math?

6. What pedagogical knowledge for teaching mathematics do you want to know more about?

7. What aspects of the Math Mentor Program did you find to be the most helpful in supporting you as a new teacher?

8. If you were redesigning the Math Mentor Program for new teachers next year, what changes would you make?

9. If you had to sum up how you are a better teacher now than when you began the year, what three things would you identify?
November, 2007

Dear (Name),

I write to ask whether you would be willing to be interviewed regarding your experience this year in the Math Mentor Program. The interview will take approximately 30-40 minutes. We can schedule it at your convenience sometime in late May or early June.

Sometime this spring, I would also like to observe you teach a math lesson. This observation is totally non-evaluative.

I have two reasons for this request. Currently, I am enrolled in a doctoral program at Boston College. The focus of my dissertation is the study of the Math Mentor Program. My second reason is that I want to improve the program. While both teachers and mentors will be asked to complete a survey at the last session, surveys have their limitations. Many people find it easier to talk about their experience than to write about it.

You should know that any information that you share with me will be confidential. None of your comments will be passed onto either your Principal or your mentor. None of the information you provide me will be used in any evaluation process directly or indirectly or be included in your personnel file. I will tape and transcribe the interview. After I have transcribed the tape, I will give you a copy of the transcription for your review and comments. You may want to add clarifying comments. Should I include any direct quotations from your interview in my dissertation, you will be identified only by a code name, thus, providing you complete anonymity. The school and district’s identity will also be camouflaged. Arlington will be referred to as a suburb of Boston. Also, after I have written the chapter in which I summarize my interview data, I will give you a copy of the draft chapter in order to allay any concerns that you might have about anonymity.

Your insights will be enormously helpful in our effort to provide an effective math support program for new elementary teachers in our district. For your help, I will be able to offer you some additional professional development points. You will also have the satisfaction of knowing that you are making a professional contribution to your district, and perhaps to the larger community should another district adopt our elementary math induction program.

If you agree to participate in this study, could you sign the agreement at the end of this letter and return it to me. Please make a copy for yourself.

Thank you very much for your help in this project.
Sincerely,

Kathleen Bodie
Assistant Superintendent/Director of Mathematics
Arlington Public Schools
Arlington, MA 02476

I agree to be interviewed both this year and next year regarding my experience in the Math Mentor Program. I understand that the interview will be taped. I also understand that my comments will be held strictly confidential and that my identity will be anonymous in the final paper should any of my comments be quoted. I will have an opportunity to review both the transcript of the interview and the final paper.

___________________________________  __________________
Signature                                                                                                                   Date