THE EFFECTS OF A SCHOOL-BASED MATH COACHING PROGRAM ON THIRD AND FOURTH GRADE URBANTEACHERS' FACILITATION OF STUDENT MATH TALK

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This is a research paper submitted for ELCL 629/630, Research in Education I & II, in partial fulfillment of the requirements for the Masters Degree in Education at William Paterson University.

Fall 2008-Spring 2009

Abstract

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Thesis Advisor: ____________________________

The purpose of this study was to examine the effects of a professional development program conducted by a school-based math coach to increase students' discussions in mathematics lessons. Five third grade teachers and 109 third grade students, and three fourth grade teachers and 84 fourth grade students received the same professional development program in an urban school district. The professional development was conducted during grade level meetings as well as in the classroom and also during individual critiquing sessions using the reform curriculum, *Everyday Mathematics.* Teacher participants who received the professional development program had been teaching from 5 to 19 years and aged from 31 to 57 years old.

The professional development program took place over 12 weeks with the purpose of instructing teachers to ask more frequent questions and deeper questions in the form of open-ended, follow-up and guiding, and deflecting questions. Students were given unit assessments to coincide with these monthly interventions and their scores were measured to assess the interventions. Student talk time was also measured to see if teachers talked less, would students talk and discuss more.

Pre-intervention procedures included baseline observations of the teachers and students in the study. The math coach researcher measured the amount of teacher lecture time, teacher wait time before calling on a student, teacher's use of different kinds of questioning, and the amount of student talk time. Unit assessment scores were also recorded prior to the interventions as a baseline measurement. Over the course of the next 3 months, different interventions were made and additional measurements were observed by the math coach researcher.

Results indicated that the teachers were able to increase their wait times, ask more questions of all types, and decrease their talk time. Students were talking more, however, their achievement on their assessment scores did not significantly increase.

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CHAPTER I

Introduction

Overview

The National Council of Teachers of Mathematics developed national standards for K-12 mathematics education in 1989 and then updated these as the *Principles and Standards for School Mathematics* in 2000 (NCTM, 2000). Both documents focused on the reduction of rote learning in mathematics and the development of deeper understanding in mathematics for all students. In the later publication, six principles were highlighted including, *Equity, Curriculum, Teaching, Learning, Assessment, and Technology*. The principles contain recommendations on how to deliver challenging, high quality, and accessible mathematics education in order to promote mathematics success in all children.

The NCTM *Teaching Principle* describes classroom environments that are challenging and support learning. To this end, the teacher must encourage the students to use critical thinking, ask deep questions, and discuss a variety of strategies when solving problems. The NCTM *Learning Principle* states that students must become autonomous learners by taking control of their learning. Learning with understanding is necessary to achieve in mathematics and can be increased by classroom discourse and social interactions.

In addition, the No Child Left Behind law (NCLB, 2001) has put great pressure on all schools throughout America for students to achieve 100%

proficiency on all standardized test scores by 2014. School administrators and educators are questioning and revamping their educational policies and practices in order to meet the challenge of demonstrating annual yearly progress (AYP).

Because of the emphasis and goals of NCLB and the NCTM principles, most school districts have changed to a standards-based or reform mathematics curriculum which is intended to promote deeper learning of mathematics rather than traditional procedural learning. This has provided a challenge for teachers who often have been taught traditionally themselves. As a consequence, there have been many professional development efforts with the purpose of getting teachers to shift their instructional techniques towards the NCTM principles.

Most urban districts, in particular, have a special problem in that they changed to standards-based curricula several years after the NCTM Principles and Standards were published and several years after they were adopted in most suburban districts. Therefore many urban districts have fallen further behind, not only in student achievement, but also in professional development of their teachers. Effective professional development must be on-going and relevant to teachers' needs in this changing educational environment. The purpose of this literature review is to examine recent research regarding reform mathematics and professional development and apply the results to urban populations and other subgroups.

Review of the Literature

This literature review is divided into three categories of research articles. The first section contains studies that examined the effect of reform mathematics curricula which are guided by current national standards and how these instructional practices impact on student achievement. The second section presents studies that examined the effects of professional development on changes in teachers' practices. The last section of the review presents studies that examined the effects of student mathematics discussions on student achievement in mathematics classrooms.

The Effects of Reform Mathematics Curricula on Student Achievement

These studies focused on the effects of reform mathematics curricula on student achievement compared to performance by students who were using traditional curricula. These studies also looked at special populations such as urban students, English Language Learners, and low achieving students with respect to how standards-based curricula are learned by these students compared to general populations.

Riordan and Noyce (2001) conducted a study in Massachusetts comparing state standardized test scores of fourth grade students using the *Everyday Mathematics* curriculum and eighth grade students using *Connected Mathematics* with fourth and eighth grade students using more traditional curricula. All test data was from 1999 and analyzed scores of 16,332 students from 200 different schools in Massachusetts.

Several statistically significant results were published which depended upon how the data were sorted. First, regular education students who had lived in their district for 3 or more years scored higher on average when using the reform curricula compared to those using the traditional curricula. In addition, students who had been using reform curricula longer scored higher than students using reform curricula for a shorter amount of time.

Subpopulations of these regular education students who had lived in their district for 3 or more years were also analyzed. These subgroups were Asian, African-American, Hispanic, Caucasian, free and reduced price lunch, and full price lunch, male, and female. In no subgroup did those using a traditional curriculum outperform those using a standards-based curriculum. In fact, in most subgroups, the *Everyday Mathematics* and *Connected Mathematics* students scored significantly higher than comparison groups.

In a third analysis, the performance of the target students was analyzed by quartiles to see how the reform curricula addressed the needs of high, average, and low achieving students compared to traditional curricula. Within each quartile, the average scores of the students using standards-based curricula were higher than the students using traditional curricula.

Balfanz, Woodward, Voorhies, and Wong (2006) studied the first 4 years of utilizing the University of Chicago School Mathematics Program (UCSMP) reform mathematics curricula in three high-poverty middle schools in Philadelphia. Each of the three public schools in the study had student populations of approximately 1,000 with 12 teachers teaching mathematics, though each school only had one secondary certified mathematics teacher on staff during the 4 years of the study. Four separate analyses were conducted using multiple methodologies. The first analysis measured school implementation levels. The second analysis measured students' performance in mathematical problem-solving using the Stanford 9 test. The third analysis measured mathematics growth between fifth and eighth grade and the fourth analysis tied student achievement to implementation levels. Analysis 1 showed that comprehensive reform can be implemented in high-poverty middle schools. The results of analyses 2 and 3 showed that students in schools undergoing reform scored higher than students in control schools. Analysis 4 showed that schools with higher levels of implementation of the reform model produced higher student achievements.

Even though all three schools experienced significant achievement increases during the study, the gains were not enough to meet the dictates of NCLB or to close the achievement gaps that exist in urban middle schools. The achievement gains were due to a whole-school reform model, reform mathematics curricula, and increased professional development and teacher support which were integrated together in this urban school. The researchers suggested further studies on reducing urban teacher mobility, providing effective extra help to low performing students, and obtaining higher levels of implementation for greater achievement gains.

Carroll (1997) analyzed the results of third-grade students using UCSMP, later named *Everyday Mathematics,* on the Illinois State Mathematics Test at 26 schools in the greater Chicago metropolitan area. Carroll compared test scores of students who were being taught with this reform curriculum to the scores of those who were being taught with a traditional curriculum. He analyzed the achievement tests of 1,885 third grade students in 26 Illinois public schools in the areas of the six strands of mathematics: number concepts and skills, measurement, algebra, geometry, data, and estimation.

The most significant results were that of the UCSMP students who had had the curriculum since kindergarten only 2% failed to meet state goals and 54% exceeded state goals. Scores on the content strands were also analyzed where the UCSMP curriculum had been utilized since kindergarten. There was also a significant increase in all strands except algebra in one large school district. Overall results showed that the districts that had used UCSMP had achieved a higher score than the districts that were using traditional curriculum.

Similarly Fuson, Carroll and Drueck (2000) conducted two studies which showed positive results for reform curricula which used teaching techniques envisioned in the NCTM *Standards.* These teaching techniques included solving problems in context and using manipulatives and tools to facilitate thinking rather than traditional approaches which stressed number facts and algorithms. The researcher was attempting to conduct a multi-year longitudinal study to be able to follow the same students in second and third grades. Students were administered the Northwestern University Longitudinal Study in both years.

The first study used number sense test questions on concepts related to whole numbers and multi-digit computation and compared test scores from 343 heterogeneous second grade students in 22 classes who used the *Everyday Mathematics* curriculum in the Chicago area. They were compared against 29 second grade students in an upper middle class school in the San Francisco area, and 33 second grade Japanese students from a middle class school in Tokyo both using traditional curricula. Questions taken from their respective textbooks were intended to examine the symbolic computational abilities of the students. EM students had higher achievement scores on questions regarding number sense, place value, and multi-digit computations compared to the San Francisco and Tokyo students.

The second study used 620 heterogeneous third grade students in 29 classes using the *Everyday Mathematics* curriculum and included 236 students from the first study whose results were compared to 1,800 students who had taken the NAEP. The computation questions in this study were both symbolic and problems in context. There were questions on geometry, data, and reasoning and the questions were taken from a variety of sources. EM students had higher achievement scores compared to the NAEP students using traditional curricula on problems that were more conceptually based.

The overall results showed that EM students performed higher than students using a traditional curriculum. However, the EM students were outperformed by the Japanese students using a traditional curriculum. Because some of the comparisons made were between students of different socioeconomic groups and different countries, the comparisons were not unbiased though conclusions and tendencies definitely supported the reform movement.

Bottage, Rueda, LaRoque, Serlin, and Kwon (2007) examined how learning disabled students performed when taught with Enhanced Anchored Instruction (EAI) in a reform mathematics setting. A variety of measures were used including pre-tests, post-tests, a control group, and observations. One hundred middle and high school students receiving special education services in self-contained special education classrooms were taught. The participants were assigned to two different sequences. Both groups were given a pre-test from the Iowa Tests of Basic Skills which confirmed the low achievement of the students. During the next 4 weeks, Sequence A received reform mathematics lessons taken from Kim's Komet (EAI) along with their regular lessons. Sequence B was the control group and was taught only with regular lessons. A post-test was given to both groups. In the next phase Sequence A went back to only using the regular lessons while Sequence B received the EAI lessons. A post-test was administered to both groups to see if Sequence B replicated the performance of Sequence A.

The results showed that using reform curricula in special education settings had the potential for Mild Learning Disabled (MLD) students to develop deeper conceptual understandings of mathematics. MLD students showed improvements in problem-solving skills and mixed results for computation. The researchers concluded that MLD students could learn relatively complex concepts and these students exceeded their teachers' expectations in this area, despite a significant deficit in their computational skills. Considerable modifications were made to curriculum and the instructional materials were restructured in order for MLD students to comprehend the content.

Woodward and Brown (2006) studied 53 middle grade mathematics students in two different comparable school settings with the purpose of determining whether the *Equity Principle* of the NCTM Standards applied to students who were considered at risk for special education services in mathematics. The students did not have Individualized Educational Plans for mathematics, but most had IEPs for reading. Performance tests were administered to measure concept development as well as students' attitudes towards mathematics in a comparison group and an intervention group.

The 25 students in the intervention group received only 55 minutes of mathematics instruction daily which were all integrated together. The comparison group of 28 students received 80 minutes of mathematics instruction daily where the first 55 minutes was integrated instruction and the last 25 minutes was used for basic skills practice using traditional algorithms and worksheets.

The results were somewhat surprising in that the intervention group outperformed the comparison group in conceptual development, attitudes towards mathematics, and on standardized test scores despite the additional time spent in remedial instruction. However, since the conceptual test questions were not designed to assess basic skills, it is not surprising that the effects of the additional time spent by the comparison group were not evident on the test. In addition, the students were seemingly disengaged during basic skills practice in the comparison group thus contributing to lower attitude scores.

Post and Harwell (2008) studied the results of sampling 1,400 middle school students who had been taught mathematics for the past 3 years using the standards based curriculum *Connected Mathematics* (CMP). The researcher studied 5 different districts ranging from high to low SES groups, urban to suburban, and variations in rationale for district adoption of curriculum. The researchers used the students' mean scores on the Stanford Achievement Test to measure their achievement compared to the mean scores of comparison students who had also taken this test in different parts of the U.S.

Test scores were analyzed statistically and were consistent with previous research and showed that urban disadvantaged districts scored lower than suburban advantaged districts. Not surprisingly, urban districts contained a higher population of ethnic minorities. Interestingly, in all subgroups, the CMP students' problem-solving and open-ended subtests showed higher results than their paper-and-pencil procedures subtest. Prior mathematics achievement was a strong predictor of future mathematics success.

Ginsburg-Block and Fantuzzo (1998) evaluated the efficacy of NCTM standards-based instructional techniques in urban settings with elementary students. The techniques of problem solving and peer collaboration were studied to determine the effects on achievement, motivation, and self-concept of 104 urban low-achieving third and fourth graders of low SES levels. There were 53 boys and 51 girls ranging in age from 8 to 12 years old and 68% of the participants were African-American. The rest of the students were Asian, Caucasian, and Hispanic.

There were 3 test groups; problem-solving (PS) only, peer collaboration (PC) only, problem-solving and peer collaboration (PLUS), and a control group. The results for problem-solving only and peer collaboration only groups both showed positive increases in all areas: achievement, motivation, and self-concept. This was consistent with prior research as hypothesized by the researchers. The PLUS group which combined PS and PC also showed increases in all areas. However, the results were not statistically different from just PS or PC alone.

The Effects of Professional Development on Changes in Teachers' Practices

This category of studies examined classroom practices that have been affected by professional development.

Hill and Ball (2004) conducted a study on the effectiveness of the California Mathematics Professional Development Institutes (MPDIs) which took place during 1-3 week periods during the summer of 2001 with follow-up surveys during the following school year. The purpose of the MPDIs was to increase the mathematics content knowledge of teachers through intensive professional development. Out of approximately 2,300 elementary school teachers who attended the summer programs, only 398 teachers were surveyed.

The results showed that there was a significant increase in mathematics knowledge both in teachers who had a high level of mathematics knowledge and in teachers who were less able in mathematics prior to entering the institute, thus endorsing professional development. The duration of the institute ranged from 1-3 weeks and the length of the program was a significant predictor of effectiveness with teachers who had more hours of professional development generally learning more. Further topics for more comprehensive study should include teacher characteristics such as motivation, educational background, and teaching methods, as well as institute characteristics such as how content is addressed, treatment of mathematical ideas and the tasks in which the teachers participate.

Garet, Porter, Desimone, Birman, and Yoon (2001) used a national probability sample and surveyed 1,027 mathematics and science teachers from 358 different school districts throughout the United States to compare the effects of different characteristics of professional development on teachers' learning and self-reported changes in classroom practices. These teachers had all attended funded professional development activities through the Eisenhower Programs. School districts were sampled proportionally to how many teachers attended and to the size of the grant.

The researchers found three core features in professional development activities which positively impacted teachers' skills and knowledge. These activities focused on content knowledge, having opportunities for active learning, and having coherence with other learning activities. The study also indicated that there were structural features which also affected teachers' knowledge. They were the form and duration of the professional development activities and having teachers participate together from the same school, grade, or subject. Incorporating both the core and structural features into professional development were indicators of more effective professional development which showed an increase in teacher learning and self-reported changes in classroom practice.

Saxe, Gearhart, and Nasir (2001) included students and teachers from 23 classrooms who were studying fractions. They were divided into 3 groups based upon the curriculum that was being used and the type of professional development that they were given. The first group of 9 teachers called the IMA group used a reform curriculum. Their first meeting was a 5-day summer institute which was followed by 13 additional focused content-based professional development sessions given at regular intervals throughout the school year. The second group of 8 teachers called the SUPP group used the same reform curriculum as the IMA group and participated in 9 additional professional development meetings during the school year. These meetings were intended to provide support to the educators based on what they felt they needed help with and were not content-based. They were used for reflective discussions of strategies and problems in order to share their experiences in a professional supportive community. A facilitator ran the meetings, but did not provide direction or instruction. The facilitator compiled requests from the teachers to discuss during meetings, sent out meeting reminders, and kept the teachers on topic. The third group of 6 teachers called the TRAD group used a traditional curriculum and did not receive any content-based or supportive professional development during the year.

The results of the study showed that the IMA group outperformed both the SUPP and TRAD groups in their conceptual abilities. With regard to computational abilities, the IMA and TRAD groups outperformed the SUPP group. Both the IMA and SUPP groups benefited from professional development. However, the IMA group benefited more from the focused content instruction compared to the support group. In addition, this study supported the idea that using a reform curriculum combined with focused professional development may result in increased conceptual understanding and equivalent computational skills compared to traditional practices.

Ross and Bruce (2007) examined the technique of self-assessment for improving student achievement and increasing teacher change leading to their professional growth. This study followed a Grade 8 mathematics teacher in a comprehensive year of professional development which incorporated self-assessment, in-service professional development, peer coaching, and external follow-up. This teacher was selected from a qualitative study done previously by the author and had benefited the most in the previous study. The teacher was observed on 5 occasions from September to June during the school year. A self-assessment tool was the key instrument utilized for measuring changes in his practice. In order for self-assessment to be successful, there had to be other methods of professional development incorporated into the program such as in-service, peer coaching, and external observations and follow-up.

The teacher based his instructional practice and revisions on how his students were achieving in the classroom. Without this control, self-assessment tended to be more positive than it deserved. In addition, peer coaching enabled the teacher to incorporate more innovative instruction in his lessons which positively impacted student achievement and instructional practice.

In a slightly later study by Bruce and Ross (2008), they examined how peer coaching affected mathematics teaching practices and teachers' beliefs as well as their impact on student learning. Twelve teachers in Grades 3 and 6 participated in this intensive professional development activity over a 6-month period. Four sessions of instruction were observed by the researchers and at least 3 additional sessions were observed by peers. Teachers worked in pairs and had a range of mathematics teaching styles from traditional to reform. Data were collected from 4 teacher observations, online self-assessments at the beginning and end of the study, peer coaching summaries from 3 observations, teacher-pair interviews at the conclusion of the study, and the researchers' field notes on the professional development sessions.

There were 3 key findings from this study. First, teachers altered their teaching practices towards a more standards-based constructivist approach. This shift encompassed more open-ended student tasks which were more engaging and encouraged multiple solutions. The largest increase in this section was in student-student interaction. Teachers gave credit for these changes in their practice to peer coaching and to the mathematics training they were given. These two pieces of the professional development program reinforced each other.

Secondly, the professional development program had a positive effect on the teachers' confidence in themselves. Part of the increase was because of validation of their teaching methods and being able to work collaboratively rather than in isolation. Some teachers initially lost confidence, but as the study progressed, they were able to implement new ideas that were shown at the professional development sessions. This caused their confidence to grow as they shared positive experiences with their peers.

Thirdly, the participants reflected more explicitly with peer coaching and it created a forum for sustained conversations about their teaching practices and how to improve them. Peer coaching was more successful when the teachers were located closer together. Initially some pairs were reticent to share honest information with each other. However, once the pairs established more open communication with each other, dialogue about pedagogy because more change-oriented.

Schorr, Firestone, and Monfils (2003) conducted a landmark study in the state of New Jersey which had conflicting findings. Through the interviews and observations of 63 teachers, teachers reported that they had changed their teaching practices to be compatible not only with the standardized state test, but also with state and national standards. These teachers were selected from two large sample groups which were surveyed for predisposition for either direct instruction or inquiry-oriented instruction. Teachers who scored at extremes on both scales were selected. Another sample group was obtained from school districts throughout the state of teachers who had participated actively in professional development programs. The combined sample of 63 teachers contained a cross-section of teachers from various District Factor Groups (DFG); a composite measure of district wealth which takes into consideration family income, occupation, poverty, and educational levels. The majority of the teachers were observed at least twice and there were a total of 121 classroom observations.

Researcher observations were coded by category and frequency. The research suggested that teachers had not changed their basic instructional approach, but had incorporated specific strategies with their students such as using manipulatives, group work, and real-world connections. They also found that teachers were not assigning different mathematical tasks than they had previously assigned. The tasks assigned centered on procedures, routines, and definitions, rather than developing conceptual knowledge. Another central observation was that classroom discourse was not substantive, but usually focused on a single strategy and simply getting the correct answer.

The conflicting findings were that even though teachers thought they had changed a lot and were using standards-based methods, direct observation showed they had not changed their basic instructional approach. The study concluded that without effective professional development on changing teaching practices, there are very little changes in teaching practice simply because of changes in state testing.

The Effects of Student Mathematics Discussions in the Classroom on Student Achievement

Studies in this section are about introducing mathematics discussions in mathematics lessons and its effect on student learning and understanding.

Hufferd-Ackles, Fuson, and Sherin, (2004) conducted an intensive year-long case study in an urban elementary classroom with Latino children. They created a *math-talk* learning community in one reform mathematics classroom and studied its impact on student understanding. Four teachers were initially observed throughout the first year of the analysis. One bilingual Spanish teacher, Ms. Martinez became the center of this case study for the second year because she began the first year by teaching in a traditional manner and had made dramatic changes in her teaching practices over the course of the year. During the second year of analysis, there were numerous teacher interviews, teacher meetings, audio and video recordings, and analyses of student discourse in her classroom.

Four learning paths emerged. In one pathway they observed shifting from having the teacher as the only questioner to having both students and teachers asking questions. In another pathway they observed shifting from having the teacher explain the answers to having the students explain the answers. A third path involved shifting from having the teacher as the source of all mathematics ideas to having students' ideas also directing the classroom lesson. The fourth path was shifting from having the teacher direct all activities to having the students actively listening and engaged in student to student discussions and taking responsibility for their own learning.

The 4 developmental paths noted above were examined individually and together. It was observed that growth occurred simultaneously in each of the paths. The authors believed that this math-talk framework was successfully developed because of the motivation of Ms. Martinez to change her practice, the presence of the research-based curriculum, the support of her administrators in reform practices, and weekly feedback meetings with the researcher. This research study has become a framework for professional development across the country in building teacher and student learning communities.

Lobato, Clarke, and Ellis (2005) conducted 3 mini-studies with 9 high school students during a summer program and with 8 high school students during an after school program. The research consisted of narrative notes by the teacher researcher describing the 30 hours of each mini-study. The purpose of the study was to limit the teacher's role as the sole source of information to allow the students to develop and explore mathematical concepts. The teacher's actions concentrated on initiating and eliciting behavior; with initiating behavior being used to stimulate mathematical thinking by introducing new mathematical ideas in classroom discussions and eliciting behavior being used to determine how students interpret what the teacher has introduced. Eliciting usually occurred when the teacher wanted to draw out or lengthen student explanations of mathematical problems. The first episode examined teacher initiating by describing a new concept, the second episode examined the teacher initiating by summarizing student work so that new information was inserted by the students, and the third episode examined the teacher providing information so that students could test their own ideas.

By redefining and limiting teacher telling in a positive constructivist manner as communication which increases students' mathematical development rather than that which shows what the teacher knows (rather than what the student knows), offered a range of opportunities for changes in teaching practices which could benefit a reform mathematics classroom. Several students in this classroom, when given the opportunity, were able to explore mathematical problems in a way that demonstrated greater understanding and conceptual development.

Franke, Webb, Chan, Battey, Ing, Freund, and De (2007) studied the conversations in 3 lower elementary classrooms in a large urban school district in Southern California. Classroom activities were videotaped and audiotaped to capture accurate observations of actual conversations and dynamics between students and teachers. The researchers looked at what teachers said after the initial question they posed to engage students in mathematical conversations in the mathematics classroom. When teachers asked additional questions about specific aspects of student answers without giving away the answers, there were different patterns of student participation and conversation that emerged. Teaching practices that included asking sequences of questions were present in the classrooms and these practices had varying degrees of success in obtaining correct student answers. Planning out different kind of questions and thinking beyond the initial questions affected the length and breadth of student discussions that took place as well.

Huang, Normandia and Greer (2005) examined the relationship between teacher discourse and student discourse in one secondary mathematics classroom at a private suburban high school in central New Jersey over a 3-month period. Data for this case study were obtained through 65 hours of observations, audio-taping, interviews, and relevant instructional artifacts which were transcribed and coded for levels of mathematics knowledge structures which occurred during mathematics discussions.

The results showed that the higher level features of teacher discourse do not enable students to speak at this level simply through classroom discussion. In order to stretch students' discourse to higher levels, the teacher had to put students in the position of acting as the teacher. In these situations, students were able to demonstrate higher level discourse that the teacher had exposed them to during lessons. This case study showed that mathematics talk does not occur naturally through discussions, but needs to be nurtured and encouraged in ways that may be time-consuming, but useful in constructing student knowledge. A further conclusion was that thorough understanding of mathematical concepts by students is created by students' abilities to talk mathematically.

Emanuelsson and Sahlstrom (2008) investigated classroom interactions and their relationship between learning and participation. Two classrooms were used, one in the United States and one in Sweden. The main source of data was classroom videos. The classroom in Sweden was characterized as highly participatory, but low in student mathematics discourse. The classroom in the United States was characterized with low brief phrases by the students and the participation was closely guided by the teacher. In the Swedish classroom the students demonstrated limited possibilities to acquire the main mathematical idea and there was little shared understanding between the teacher and the students.

The researchers concluded that the teacher should provide more direction on the mathematical content in order to focus more on developing the mathematical concepts despite their high level of participation. In the U.S. classroom, the researchers concluded that if the regulated participation were to be opened up, there might be less mathematical learning taking place. The implied contradiction between teacher control versus student participation was challenged in this study and would benefit from further investigation.

Baxter, Woodward, Voorhies, and Wong (2002) conducted a 9-week study with 28 fourth-grade students and their teacher, Ms. Nelson, in a reform mathematics classroom using the *Everyday Mathematics* curriculum. The teacher held many constructivist beliefs and had decided that she wanted to have more student-centered discussions in her classroom which included 3 low performing students. One of these students had an IEP and 2 were being considered for special education. The data for this study were obtained through video and audiotapes, informal interviews, and observations. A paraprofessional was present all of the time during the study to assist the 3 target students.

Performance assessments were given to all of the students once a week and were in the form of an open-ended problem which required thought and explanation. Students worked in pairs or triads to complete the assessment and the 3 target students were not put in the same group together. After the groups finished the problems, they were presented to the class in the form of a discussion. Additional time for practice was provided to the target students in the form of remediation with the paraprofessional before or during school time whenever possible. Throughout the 9 weeks of study, there was an observable shift towards increased student participation and discussion. From week 3 to week 9 the teacher showed a decrease in social scaffolding and an increase in statements prompting mathematical reflection. During discussions the students showed an increase in making claims with supporting statements and reporting their strategies. The target students presented unique challenges to classroom discussions in that when there was a notably fruitful in-depth mathematical discussion, it was difficult to include a wide range of students because the students in the discussion usually were the most verbal and capable mathematics students. In addition, the target students' participation exhibited less sophisticated thinking and it was unclear whether they could understand multiple methods for solving a single problem. Nonetheless, it was concluded by the researchers that the discussion rich environment was preferable to an isolated environment with only low performing students because the low performing students would not be exposed to higher level thinking otherwise.

Falle (2004) developed a model for teaching mathematics which incorporated specific language arts techniques, use of specific language, and use of questions to promote student discussions in the mathematics classroom. The conversations of 3 high school students were studied during group tutoring sessions conducted after school in rural Australia. The 3 students were highly motivated and wanted to develop more confidence and knowledge in mathematics. The researcher's study was limited, but benefited by being a very small group without curriculum constraints in an informal after school setting.

Students were first asked to work together to figure out the square root of a number without using a calculator and explain their reasoning. The second problem was to determine the dimensions of a rectangle with a fixed area. The use of questions in conversation and guided language by the tutor enabled her to uncover what the students understood and misunderstood, thereby encouraging focused conversation about mathematics which led to cognitive development and greater understanding. The researcher concluded that because the students exposed their misconceptions verbally, she was able to focus the discussion at that moment which led to deeper mathematical understanding.

Summary of the Literature Review

As presented in this literature review, most students performed at higher achievement levels when taught with reform mathematics curricula such as UCSMP *Everyday Mathematics* and *Connected Mathematics.* While the majority of the research presented in this review found that reform mathematics instruction enabled most students to perform at significantly higher achievement levels, these findings were not as dramatic for special populations of students.

The research studies conducted by Carroll (1997), Fuson, Carroll, and Drueck (2000) and Riordan & Noyce (2001) examined the results of using reform curricula on general populations of students. All of their results showed that students perform at higher levels when taught with standards-based curricula compared to traditional curricula. Part of the reason for this could simply be that because the standards-based curricula are more closely aligned to the standardized tests, the students will perform better. Other subsets of their research showed that these students performed at higher levels when demonstrating conceptual understanding of mathematics concepts compared to isolated computational questions.

The research studies done by Post and Harwell (2008), Balfanz, MacIver, and Byrnes (2006), and Ginsburg-Block and Fantuzzo (1998) examined the performance of students in urban settings that used a reform model. One the whole, students in urban districts, containing a higher proportion of low-achieving, low income, ethnically diverse students, demonstrated higher levels of conceptual development compared to procedural knowledge. Since conceptual development has been deemed more important in the long term compared to computation by the NCTM standards, these results support using the reform model in urban settings.

The research of Bottage, Rueda, LaRoque, Serlin, and Kwon (2007) and Woodward and Brown (2006) focused on special education settings. The results showed that special education students could learn effectively from modified reform curricula. These students significantly improved their conceptual understanding in mathematics, but showed lower achievement in computational practices. These results are encouraging for special education students since reform curricula stress building conceptual understanding over computation.

Professional development is another key area in which research has been conducted to show how changes in teaching practices affect student achievement. The research by Garet, Porter, Desimone, Birman, and Yoon (2001), Hill and Ball (2004), Saxe, Gearhart, and Nasir (2001), and Schorr, Firestone, and Monfils (2003) supported the necessity of professional development to enable teachers to really change their practices. These studies also concluded that professional development needs to be intensive, focused and relevant for the teachers to change. In addition, 2 studies by Bruce and Ross (2007 and 2008) explored the effects of different aspects of professional development such as self-assessment and peer coaching. They concluded that in order to successfully change teachers' instructional methods, having a combination of related professional development activities was necessary

Additional research literature was examined to see if there were positive achievement effects when there were more student mathematics discussions in mathematics classrooms. Because many teachers have learned by simply listening to their teachers, instead of by talking when they were in school, this practice has been slow to catch on, especially in settings where the students are not able to explain themselves due to language acquisition challenges, lack of understanding, or other issues. The research cited does support the idea that by having students explain their mathematical rationale, they are, in fact, increasing their comprehension and developing a better understanding of the mathematics involved.

The studies by Franke, Webb, Chan, Battey, Ind, Freund, and De (2007), Hufferd-Ackles, Fuson, and Sherin (2004), Huang , Normandia, and Greer (2005), and Lobato, Clarke, and Ellis (2005) all increased student discussions using a variety of teacher techniques in the mathematics classrooms. The implications are that the more actively the students discuss mathematical concepts, will lead to greater and deeper mathematical understandings. The task of improving student discussions became more difficult in an inclusion classroom as shown by Baxter et al. (2002).

The research done to date has focused on the benefits of reform mathematics, implementing effective professional development programs having teachers ask more questions so that students talk more. Because much of the research on student mathematics discussions focused more on the teacher rather than the students, there is a need to focus on the students and the direct results on student achievement. The research study undertaken here is a compilation of these topics as it takes place in a reform mathematics setting, uses professional development done with an on-site math coach, and focuses on greater achievement through student discussion. All of the research to date has been completed by outside researchers who were not part of the schools' permanent framework. Using an on-site math coach as the researcher may add more validity to the results as more school districts create these positions to reach their mathematics goals.

CHAPTER II

Statement of the Problem

The No Child Left Behind law (NCLB, 2001) started off this millennium focusing on higher standards for all students in the United States of America. The requirement for 100% proficiency by all students on all standardized test scores by 2014 has caused school administrators and educators across the country to question and revamp their educational policies and practices. This challenge, though, has been primarily in terms of increasing standardized test scores and by demonstrating annual year progress (AYP) for all schools and districts.

In contrast to the testing pressures of NCLB, the National Council of Teachers of Mathematics developed national standards for K-12 mathematics education in 1989 (NCTM, 1989) and revised this document as the *Principles and Standards for School Mathematics* in 2000 (NCTM, 2000). Both of these documents focused on the reduction of rote learning in mathematics and the development of deeper understanding of mathematics for all students. The later document incorporated six principles for mathematics at all levels including values for addressing issues of *Equity*, *Curriculum*, *Teaching, Learning, Assessment,* and *Technology*. NCTM's recommendations were on how to deliver challenging, high quality, and accessible mathematics education in order to promote mathematics success in all children. These principles along with the mathematics content standards in the document set the tone for mathematics education, and along with NCLB, are two powerful forces impacting on the teaching and learning of mathematics across the nation.

In particular, the NCTM *Teaching Principle* describes classroom environments that are challenging and support learning. Creating this environment is built around the teacher encouraging the students to use critical thinking, ask deep questions, and to discuss a variety of strategies when solving problems. The NCTM *Learning Principle* states that students must become autonomous learners by taking control of their learning. Learning with understanding is necessary to achieve in mathematics and can be increased by classroom discourse and social interactions.

Implementing the teaching and learning principles, however, is not a simple matter. In part because of the NCLB pressures, and in part because teachers have been taught differently themselves, many teachers have not been able, or perhaps willing, to change their teaching styles to promote different kinds of classroom discourse and inquiry intended to promote deeper learning of mathematics rather than rote procedural learning. This problem is particularly acute in urban districts where standards-based curricula were introduced several years after the NCTM Principles and Standards were published and several years after they were adopted in most suburban districts.

The problems faced by urban school districts in implementing NCTM's emphasis on teaching and learning emphasizing students' responsibility for participating in mathematics discussions and for constructing their own knowledge have several origins. First, language and culture play an important part in mathematics learning today. The language of mathematics is very specific and creates many challenges in its acquisition. When teaching in a language other than English, there are nuances to that language which do not translate directly. Second, NCTM also defines teachers' roles as facilitators rather than imparters of knowledge. Consequently, frequent deep mathematics discussions in the classroom are a natural required result of teachers acting as facilitators rather than as lecturers. The problem in urban districts comes in because in many of these districts a majority of the students are English Language Learners (ELL). This makes discussion in English about mathematics a very difficult task for students even if teachers are trying to engage them more actively in discourse. In addition, many of these students may not be encouraged to talk with adults at home, in any language, and certainly are not encouraged to disagree with their teachers, which is part of the discourse process in a standards-based mathematics classroom. Even if teachers wanted to act as facilitators, this transition from traditional teaching to facilitating may not come naturally, and extensive training is required to make it happen.

Consequently, there are scores of professional development efforts in urban school districts across the country with the purpose of getting teachers to shift their instructional techniques toward the ideals of the NCTM principles. However, because most professional development opportunities are limited in time and scope due largely to contractual and monetary considerations, their effectiveness is limited as well. In order to maximize the effects of professional development activities, therefore, it is necessary to provide urban teachers with more appropriate long-term professional development to help them develop skills for promoting richer discussions during mathematics lessons in the context of the kinds of students with whom they are working. One method for doing this which has gained popularity in recent years is to have school-based math coaches provide ongoing professional development for teachers during their regular school day. Often these math coaches come from within the schools and district and so are in a good position to know and provide the kinds of professional development experiences that teachers need in order to effectively change the way they perform in the classroom.

This present study investigated the impact of one such urban school-based math coach's efforts to provide professional development for third and fourth grade teachers in the area of leading discussions during mathematics lessons.

Purpose of the Study

The purpose of this study was to determine the effect of training teachers to use more student-centered approaches to classroom discussions as a means of increasing students' understanding and active engagement in mathematics learning. Specifically this study examined the effects of professional development conducted by the on-site math coach on urban third and fourth grade teachers' uses of discussion strategies during mathematics lessons. The study also focused on the effect of implementing these strategies on students' participation and changes in their learning.

Definition of Variables

Math Coach

In this study the term math coach refers to a school-based teacher who provided professional development training during the regular school day. The professional development consisted of mini-workshops held during bi-weekly grade level meetings and through individual classroom room visits with teachers during which the math coach engaged in co-teaching, modeling of instructional techniques, and critiquing of mathematics lessons. The four methods used by the math coach in this study are described below.

Grade level meetings. In this study grade level meetings refer to meetings of all teaching staff within one grade conducted by the school-based math coach with the purpose of improving instructional techniques for using interactive student-teacher discussions during mathematics lessons. These meeting usually lasted for one period, or one-half hour, and usually occurred twice per month.

Modeling of instructional techniques. In this study the school-based math coach visited third and fourth grade classrooms with the purpose of showing the teachers, or modeling, how to use the techniques presented at the grade level meeting in their classrooms.

Co-teaching. In this study co-teaching refers to a technique used by the school-based math coach which was when both the math coach and the teacher presented the lesson to the students. The purpose of this technique was to provide support to the teacher without interrupting the lesson.

Critiquing of mathematics lessons. In this study critiquing of mathematics lessons took place after the math coach observed a lesson and then met with the teacher for a private discussion between the math coach and the teacher during the school day or before or after school. The purpose of critiquing of mathematics lessons was for the teacher to receive feedback from the math coach on techniques the teacher was attempting to change during her instruction.

Discussion Techniques Used By Teachers

There were five variables related to discussion techniques used in mathematics lessons that were examined in this study. These are described below.

Teacher talk time. In this study teacher talk time refers to the amount of time spent by the teaching in explaining and modeling concepts and procedures, delivering instructions, asking questions, and managing interactions and behavior of students during the lesson.

Wait time. In this study wait time refers to the amount of time the teacher waited for students volunteer to speak after she asked a question or made a statement and before she spoke again or called on a volunteering or non-volunteering student to answer.

Open-ended questions. In this study open-ended questions refer to questions made by the teacher which cannot be answered with a simple yes or no. Open-ended questions are posed in such a way as to obtain maximum student talk as a response and are usually why or how questions.

Follow-up or guiding statements. In this study follow-up or guiding statements refer to the teacher's comments following students' initial responses to her questions or students' self-initiated comments. The purpose of the follow-up or guiding statements was to direct and extend students' responses.

Deflecting statement or questions. In this study a deflecting statement or question refers to remarks made by the teacher in response to a student's question and serves the function of turning the responsibility for answering the question back to the student. The purpose of a deflecting remark is to enable students to think on their own and to provide them with more opportunities for participating in the class discussion. An example of a deflecting statement would be, "And how can you figure that out?" or "Where can you look for additional strategies?"

Student Math Talk

In this study student math talk refers to the amount of time students spent speaking during a mathematics class. This talk could have been in response to a teacher's question or as a comment to a student's or teacher's observations during mathematics lessons. It also refers to the frequency or number of all students' comments during a mathematics lesson (e.g., 10 student comments vs. 20 student comments).

Hypotheses

It was generally expected that when teachers were provided with professional development by the school-based math coach on effective mathematics classroom discussion techniques that the amount of student participation in discussions would increase and that the amount of teacher talk time would decrease. It was also expected that the kinds of statements and questions made by teachers would change compared to before the professional development took place.

Hypothesis 1

It was hypothesized that after teachers participated in the mathematics discussion improvement program, there would be less teacher talk time during mathematics lessons than before they participated in the professional development with the math coach.

Hypothesis 2

It was hypothesized that after teachers participated in the mathematics discussion improvement program, they would increase wait time after posing a question to students in mathematics lessons compared to before they had participated in the professional development with the math coach.

Hypothesis 3

It was hypothesized that after teachers participated in the mathematics discussion improvement program, they would ask more open-ended questions to obtain maximum student mathematics talk compared to before they had participated in the professional development with the math coach.

Hypothesis 4

It was hypothesized that after teachers participated in the mathematics discussion improvement program, they would make more guiding statements or ask more follow-up statements as following students' initial responses compared to before they had participated in the professional development with the math coach.

Hypothesis 5

It was hypothesized that after teachers participated in the mathematics discussion improvement program, they would increase the number of deflecting statements and/or questions compared to before they had participated in the professional development with the math coach.

Hypothesis 6

It was hypothesized that after teachers participated in the mathematics discussion improvement program, students would exhibit more math talk time and a higher frequency of comments and responses compared to before their teacher had participated in the professional development with the math coach.

Hypothesis 7

It was hypothesized that after teachers participated in the mathematics discussion improvement program, students would achieve higher assessment scores on their unit tests compared to before their teacher had participated in the professional development with the math coach.

Additional Research Questions

In addition to the hypotheses stated above, the teacher-researcher was interested in other related areas.

If the teachers did make changes such as increasing wait time, what did they do if the students do not respond?

What were the students' reactions to having time for discussions?

What relationship (if any) was there between the teachers' years' of experience and their success in implementing the class discussion strategies learned in the grade level meetings?

What kinds of classroom management techniques enabled more student participation in discussions in the classrooms?

Was there any relationship between the classroom teachers' attitudes toward teaching mathematics and their responsiveness to the professional development? To student participation?

Do teachers who like mathematics as a subject ask different kinds of questions than teachers who do not like mathematics?

What did the teacher-researcher notice about the length, depth, and amount of students' comments and questions?

Did teachers who received this professional development have students provide better and deeper explanations on open-ended questions compared to before the training?

What did the students think about these changes?

How did they react, if at all?

CHAPTER III

Methods

Participants

Participants in this study included all of the third and fourth grade teachers and their students from an urban elementary school in Northern New Jersey. The school was 1 of 16 elementary schools in an Abbot school district that was ranked "A" under the District Factor Grouping (DFG) created by the New Jersey Department of Education in 1974 to measure demographic variables. There are approximately 10 variables which are used as an indicator of socioeconomic status of the U. S. citizens who live in each district. DFG has been used to compare New Jersey state testing results between schools in the same categories (NJDOE, 2000). Revisions to these districts and indicators have been made using data from the 1980 and 1990 U.S. Censuses. Rankings vary from "A" to "J" with "A" being the lowest DFG ranking.

A total of 659 students in Grades 1 through Grade 6 were enrolled in the school at the time of the study. Approximately 61% spoke Spanish as their first language at home, 33% of these students spoke English, 4% spoke Gujarati, 1% spoke Polish, and 1 % spoke other languages. Because most of the families were living below the poverty level, after-school programs were also provided to the students at no additional charge. Through this Title I Program, 86% of the students in the school received a free lunch and breakfast every day.

The participating third grade homeroom teachers and one special education teacher were all females and individually had 12, 10, 16, 5, and 8 and 3 years of teaching experience though not all in the third grade. Four of these teachers were Caucasian, one was African-American, and one was Hispanic. The fourth grade teachers were all Caucasian females and individually had 5, 15, and 23 years of teaching experience though not all in the fourth grade. One of the 3 fourth grade classes was an inclusion class which had a paraprofessional in the classroom who provided special education assistance to the special education students in the classroom in addition to the teacher.

There were 109 third graders comprised of 9 Asian, 9 African-American, 89 Hispanic, and 2 Caucasian students. There were 55 girls and 54 boys. These students comprised five third grade classes that were categorized as one bilingual (B), one gifted and talented monolingual (M-GT), one inclusion monolingual (M-I), and two monolingual regular education (M). There were 84 fourth graders in the study comprised of 7 Asian, 10 African-American, 65Hispanic, and 2 Caucasian students. There were 44 girls and 40 boys. These students comprised three fourth grade classes that were categorized as one gifted and talented monolingual (M-GT), one regular education monolingual (M), and one inclusion monolingual (M-I).

These 9 teachers and 1 paraprofessional were asked by the math coach researcher if they would participate in a study on the effect of math coaching during grade level meetings and how this form of professional development has changed the amount of student math talk in their classrooms. All teachers volunteered to participate and were interested in the research topic.

The teacher-researcher was a Caucasian female and the math coach in this school. She had 15 years of teaching experience including 2 years as a math coach. She completed this study as one requirement in earning her Master's Degree in Education, with a concentration in Teaching Children Mathematics. The math coach was responsible for coaching 22 homeroom teachers and 6 specialist teachers. Approximately 70% of her time is spent coaching classroom teachers and 30% of her time is spent on administrative projects such as reports, purchase orders, and planning for grade level meetings.

Materials

Pre-Intervention Assessment

Student assessment. The pre-intervention assessment was taken from Unit 4 of the Assessment Books for Grade 3 and Grade 4 of the *Everyday Mathematics* curriculum. The content of these units was multiplication and division for Grade 3 and adding, subtracting, and estimating decimal computations in Grade 4. The assessment was a combination of short answers and one open-ended question. The open-ended question required students to show reasoning or provide explanations as to how they arrived at their answers. The Grade 3 assessment is included in Appendix A, and the Grade 4 Assessment is included in Appendix B.

Teacher-Researcher Journal

The math coach-researcher kept a daily journal in order to record her observations of teachers and reflect on the professional development topics and techniques for increasing student mathematics talk in the third and fourth grade classrooms. A stopwatch was used to measure the amount of teacher talking versus student talking times. Samples pages are included in Appendix C.

Intervention Materials

Everyday Mathematics Curriculum. The curriculum used was *Everyday Mathematics* (2007) for Grade 3 and Grade 4. Short answer and open response questions were taken from the Unit 5 and Unit 6 written assessments in the 2007 Edition Assessment Book. Third grade Unit 5 covered decimals and place value and Unit 6 covered geometry. Fourth grade Unit 5 covered multiplication and Unit 6 covered division. The assessments were based on 100 total points and the open response questions required students to describe how they arrived at a solution and to explain their reasoning. This material can be found in Appendices D through G.

Grade Level Meeting Agendas. The math coach-researcher created meeting agendas which were used during the study. The agendas focused the grade level meetings and followed the sequence of the research. These agendas are contained in Appendices H through S.

Classroom Supplies

Supplies such as erasable markers, slates, slate erasers, overhead transparencies, overhead projector, and mathematics manipulatives which were part of the mathematics classroom were used in this study. In Grade 3 the manipulatives used were counters, area grids, base-ten blocks, geometric 2-dimensional and 3-dimensional shapes. In Grade 4 the manipulatives used were base-ten blocks, counters, and pattern blocks.

Post-Intervention Assessments

Teacher Questionnaire. A questionnaire was distributed to all the teachers who participated in the research study at its conclusion. The questionnaire asked teachers a variety of questions about the content they had taught, the professional development received during the grade level meetings, and the impact on their teaching. This questionnaire used a Likert scale, and it is contained in Appendix T.

Student Assessment. The Unit 7 assessment for Grade 3 and the Grade 4 from the *Everyday Mathematics* Assessment Book were used at the end of this study. These questions were mainly short answer and one open-ended question required students to describe how they arrived at a solution and to explain their reasoning. The topics in Grade 3 were multiplication and division number problems, and the topics in Grade 4 were probability and fractional equivalents. Scoring was based on 100 total points. The third grade material can be found in Appendix U and the fourth grade material is in Appendix V.

Procedures

Prior to the beginning of the intervention, all third and fourth grade teachers were asked if they would be part of a research project with the math coach researcher. They were told that the study was about grade level meeting professional development and increasing student mathematics talk in their classrooms. All of the teachers volunteered and were interested in improving their students' learning during the research study.

Pre-Intervention Procedures

Baseline observations. The math coach-researcher also made baseline observations in each classroom specifically noting amount of lecture time, wait time before calling on a student, use of open-ended questioning, and responses of teachers; and the amount of amount of talking time, length of responses, and type of responses of students during mathematics lessons.

Pre-Intervention Assessment. Prior to the intervention students were given an assessment which contained several short answer questions and one open response question to assess their mathematical competency and to what extent they were able to explain their methodology.

Intervention Period

For all participants in the study, the intervention took place over a 12-week period. Mathematics was taught in each classroom 60 minutes each day and, in addition to performing the administrative duties of her job, the math coach-researcher was present in each classroom 1 day per week for their mathematics period. There were grade level meetings separated by 2 weeks each for third and fourth grade teachers where either instructional strategies and skills were introduced to increase student math talk in their classrooms, or teachers and the math coach researcher shared experiences and strategies that had worked over the past two weeks. Grade Level Meetings alternated between introducing instructional strategies and sharing classroom experiences 2 weeks later. There were a total of 6 grade level meetings for each grade level.

Intervention Procedures – Week 1 through Week 12

Week 1: Grade Level Meeting #1 was used to introduce the instructional strategy of wait time and using open-ended questions.

Week 1 and 2: The 2-week period following this grade level meeting was used for the teacher and math coach to practice and refine using the instructional strategy of wait time and using open-ended questioning via 1:1 coaching, modeling, co-teaching, and critiquing.

Week 3: Grade Level Meeting #2 was used to share teaching experiences after using more wait time and open-ended questions.

Week 3 and 4: The 2-week period following was used for the math coach researcher to assess the effectiveness of the professional development using observation and unit assessment questions for the students.

Week 5: Grade Level Meeting #3 was used to introduce the instructional strategy of using follow-up or guiding statements to direct and extent students' responses.

Week 5 and 6: The 2-week period following this grade level meeting was used for the teacher and math coach researcher to practice and refine using the instructional strategy of using follow-up or guiding statements via 1:1 coaching, modeling, co-teaching, and critiquing of math lessons.

Week 7: Grade Level Meeting #4 was used to share teaching experiences after using follow-up or guiding statements.

Week 7 and 8: The 2-week period following was used for the math coach researcher to assess the effectiveness of the professional development using observation and unit assessment questions for the students.

Week 9: At Grade Level Meeting #5 the instructional strategy of using deflecting statements or questions to turn the responsibility for answering the questioning back on the student was introduced.

Week 9 and 10: The 2-week period following this grade level meeting was used for the teacher and math coach researcher to practice and refine using the instructional strategy of using deflecting statements or questions via 1:1 coaching, modeling, co-teaching,, and critiquing of mathematics lessons.

Week 11: Grade Level Meeting #6 was used to share teaching experiences after incorporating deflecting statements or questions into their lessons.

Week 11 and 12: The 2-week period following was used for the math coach researcher to assess the effectiveness of the professional development using observation and unit assessment questions for the students.

Post-Intervention Assessments- Week 12

Student Assessments. Grade 3 and Grade 4 students were given an end of unit written assessment from the *Everyday Mathematics Assessment* book. The written assessments were composed of short answer as well as one open response question. Written observations were made at the conclusion of the 12-week study by the math coach researcher to measure how much more student talk time was present during a mathematics lesson.

Teacher Assessment. Teachers were given a brief questionnaire at the completion of the study to assess the effectiveness of the professional development they received. In addition, the observational notes of the math coach researcher were compiled and analyzed to measure how much teacher talk time decreased during a mathematics lesson. A comprehensive chart outlining the research study appears in Appendix W.

Chapter IV

Results

Overview

The data in this study were used to determine the effect of a school-based math coaching program on third and fourth grade urban teachers' facilitation of student math talk. In addition, data were collected to determine the effect of the professional development program on student achievement. Specifically, the study examined teacher wait times after speaking and for allowing students to respond as well as their uses of discussion techniques intended to increase student talk time. In addition, students' performances on unit assessments for the units covered before and during the course of the study were examined.

Before the intervention began, data were collected by the math coach-researcher which served as baseline measures of the average length of teachers' wait times in seconds, the amount of time students' spoke during the observation period measured in minutes, and the frequency of types of questions that were posed by teachers and students during mathematics lessons observed. Time data were collected during two 10-minute observations before and after the intervention took place using a stop watch. Question types used were also collected during those observations and then tallied and categorized as to whether they were open-ended, guiding, or deflecting questions. The data on times, questions, and scores were used to measure the relative changes in teacher and student behaviors as a result the professional development interventions.

In addition, unit tests based on 100 points containing multiple choice, short answer, and open-ended questions were administered to students before and after each part of the intervention. Similar data were collected on the unit test for the unit covered prior to the intervention period to assess student academic performance as a function of the professional development experiences of their teachers.

Additional informal observations were made throughout the course of the interventions on students' reactions, teachers' techniques and teachers' responses to an attitude survey which was administered at the end of the interventions.

Analysis of Data

One-tailed t-tests for paired samples were used to compare changes in mean teachers' mean wait-times, students' mean talk times, and students' mean unit test scores before, during, and after the interventions. Sign tests were used to compare the change in frequency of the types of teacher questions before, during and after interventions.

Hypotheses

It was generally expected that when teachers were provided with professional development by the school-based math coach on effective mathematics classroom discussion techniques that the amount of teacher wait time after posing questions and students' participation in discussions would increase and that the amount of teacher talk time would decrease. It was also expected that the kinds of statements and questions made by teachers would change compared to before the professional development took place. Student achievement after the interventions was also expected to increase because the assumption was that they would learn better if they were given the opportunity to be more active participants in class discussions.

Hypothesis 1 – The Effects of a Mathematics Discussion Improvement Program on Teacher Talk Time

It was hypothesized that after teachers participated in the mathematics discussion improvement program, there would be less teacher talk time during mathematics lessons than before they participated in professional development with the math coach. Specifically teachers who engaged in this improvement program were expected to have more student discussion time during their mathematics lessons and less teacher lecturing time after participating in the training.

In order to test this hypothesis, the mean length of teacher talk time during two 10-minute observation periods was compared before, during and after each intervention using a stop watch using one-tailed paired t-tests. As shown in Table 1, there was a significant decrease in teacher talk time after the first intervention in January going from 6.55 minutes to 5.31 minutes ($t(7) = 2.13$, $p < 0.05$).

However, after the second and third interventions in February (mean = 5.77 minutes, (t(7) = 1.13, p = 0.25) and March (mean = 5.75 minutes, t(7) = 1.62, p = 0.10), there was not a significant difference in teacher talk times compared to the pre-intervention measure. While the mean teacher talk time did show a decrease each month compared to the baseline data, the difference was not a significant one after the first month. Thus, the results partially supported the hypothesis that teachers would talk less during mathematics lessons after they had participated in the mathematics discussion improvement program.

Hypothesis 2- The Effects of a Mathematics Discussion Improvement Program on Teacher Wait Time

It was hypothesized that after teachers participated in the mathematics discussion improvement program, they would increase wait time before calling upon and after posing a question to students in mathematics lessons compared to before their participation in the professional development with the math coach-researcher. Specifically teachers who engaged in this improvement program were expected to increase the time they waited for student responses during their mathematics lessons at all three observation points following the training sessions.

In order to test this hypothesis, the mean wait time in seconds during two 10-minute observation periods was compared before, during and after each intervention using a stopwatch with one-tailed paired t-tests. A minimum of eight

Table 1

A Comparison of Mean Teacher Talk Times in Minutes During Two 10-Minute Observation Periods Before, During, and After Interventions

	Baseline	January	t-score	Baseline	February	t-score	Baseline	March	t-score
Brandon	6.27	5.20		6.27	7.75		6.27	5.59	
Jones	7.67	4.27		7.67	4.18		7.67	6.57	
Logan	7.35	5.92		7.35	3.88		7.35	4.25	
Smith	5.70	2.60		5.70	6.70		5.70	4.87	
Rodriguez	6.60	4.43		6.60	5.30		6.60	6.90	
Lewis	4.87	5.85		4.87	4.25		4.87	6.60	
Pope	8.35	7.75		8.35	7.55		8.35	6.92	
Reagan	5.55	6.43		5.55	6.53		5.55	4.27	
Group Mean	6.55	5.31	2.13*	6.55	5.77	1.13	6.55	5.75	1.62

$^{*}p < 0.05$

wait times were measured for each teacher during each 10-minute observation period. There were significant increases in teacher wait times both individually and as a group. As shown in Table 2, the mean group data showed a significant increase in January, going from 1.73 seconds to 2.78 seconds compared to the baseline data ($t(7) = 6.59$, $p < 0.01$). There were also significant increases in February, (mean = 2.66 seconds, ($t(7) = 5.17$, $p < 0.01$) and March (mean = 2.55 seconds, ($t(7) = 5.08$, $p < 0.01$). There were significant increases in most individual teacher wait times after all three interventions although the mean wait time was the greatest after the first intervention and decreased each succeeding month compared to the baseline data. The results supported the hypothesis that teachers would increase their wait times before calling on students during mathematics lessons after they had participated in the mathematics discussion improvement program.

Hypothesis 3- The Effects of a Mathematics Discussion Improvement Program on Teachers' Open-Ended Questions

It was hypothesized that teachers who participated in the mathematics discussion improvement program would ask more open-ended questions to obtain maximum student math talk after each of the three intervention data collection points compared to the number of these questions they asked before the intervention began. Specifically teachers who engaged in this improvement program were expected to ask more questions that required more than one correct

Table 2

A Comparison of the Mean Length of Wait Time in Seconds Used by Teachers During Two 10-Minute Observations Made Before and After the Intervention in January, February, and March

	Baseline	January	t-score	Baseline	February	t-score	Baseline	March	t-score
Brandon	1.9	2.7		1.9	2.8		1.9	2.6	
Jones	1.3	2.3		1.3	2.0		1.3	1.9	
Logan	1.3	2.6		1.3	2.8		1.3	2.5	
Smith	1.8	2.5		1.8	2.3		1.8	2.3	
Rodriguez	1.6	2.3		1.6	2.5		1.6	2.4	
Lewis	1.7	3.7		1.7	3.3		1.7	3.4	
Pope	1.1	2.3		1.1	2.4		1.1	2.0	
Reagan	3.1	3.8		3.1	3.2		3.1	3.3	
Group Mean	1.73	2.78	6.59**	1.73	2.66	5.17**	1.73	2.55	5.08**

*p < 0.05

**p < 0.01

answer or a one-word answer during their mathematics lessons at all three observation points following the training sessions.

In order to test this hypothesis, the math coach-researcher counted the number of open-ended questions that the teachers asked before and after each of the training sessions during two 10-minute observation periods and compared the results using the one-tailed sign test. As shown in Table 3 there was a significant increase in the number of open-ended questions after the first intervention in January which was when the teachers received coaching and practice in asking open-ended questions ($t(7) = 0.0039$, $p < 0.01$). Eight out of the 8 teachers increased the number of open-ended questions after the first intervention compared to the baseline data. After the second intervention 5 out of the 8 teachers increased the number of open-ended questions they asked compared to the baseline data which was not statistically significant ($t(7) = 0.3633$). After the third intervention 7 out of the 8 teachers increased the number of open-ended questions they asked compared to the baseline data. This increase was statistically significant using a one-tailed sign test ($t(7) = 0.0352$, $p < 0.05$).

Hypothesis 4 – The Effects of a Mathematics Discussion Improvement Program on Teachers' Guiding Statements and Follow-Up Questions

It was hypothesized that after teachers participated in the mathematics discussion improvement program, they would make more follow up or guiding

Table 3

A Comparison of the Mean Number of Open-Ended Questions Asked by Teachers During Two 10-MinuteObservations Made Before and After the Intervention in January, February, and March

	Baseline	January	+/-	Baseline	February	+/-	Baseline	March	+/-
Brandon	3.5	5.5	+	3.5	4.5	+	3.5	6.0	+
Jones	1.0	4.0	+	1.0	2.0	+	1.0	4.0	+
Logan	2.5	4.5	+	2.5	5.0	+	2.5	3.5	+
Smith	8.0	9.5	+	8.0	6.5	-	8.0	7.0	-
Rodriguez	4.5	6.0	+	4.5	5.0	+	4.5	7.0	+
Lewis	7.5	8.5	+	7.5	6.0	-	7.5	9.5	+
Pope	2.0	5.0	+	2.0	4.0	+	2.0	6.5	+
Reagan	5.0	6.5	+	5.0	4.0	-	5.0	7.0	+
Sign Test p-value		0.0039**			0.3633			0.0352*	

*p < 0.05

**p < 0.01

statements following students' initial responses compared to before they had participated in the professional development with the math coach. Specifically teachers who engaged in this improvement program were expected to make more guiding statements and ask more follow-up questions of their students during the two observation points following the training sessions in February.

In order to test this hypothesis, the math coach-researcher counted the number of guiding statements and follow up questions that the teachers asked before and after the last two interventions during two 10-minute observation periods. These results were compared using a one-tailed sign test. As shown in Table 4, in both February and March all 8 teachers increased the number of guiding statements and follow up questions they asked compared to the baseline data. The sign test results indicated that there was a significant increase in the number of guiding statements and follow up questions after the second and third interventions in February ($t(7) = 0.0039$, $p < 0.01$) and March ($t(7) = 0.0039$, $p < 0.01$).

Hypothesis 5 – The Effects of a Mathematics Discussion Improvement Program on Teachers' Deflecting Questions

It was hypothesized that after teachers participated in the mathematics discussion improvement program, they would increase the number of deflecting statements and/or questions compared to before they had participated in the professional development with the math coach-researcher. Specifically teachers

Table 4

A Comparison of the Mean Number of Teachers' Guiding Statements and Follow-Up Questions During Two 10-Minute Observations Made Before and After the Intervention in February and March

	Baseline	February	+/-	Baseline	March	+/-
Brandon	0.5	4.5	+	0.5	3.0	+
Jones	0.0	2.5	+	0.0	2.0	+
Logan	0.0	1.0	+	0.0	2.0	+
Smith	3.5	4.5	+	3.5	4.0	+
Rodriguez	1.5	3.0	+	1.5	3.0	+
Lewis	3.0	5.5	+	3.0	4.5	+
Pope	0.0	3.0	+	0.0	4.0	+
Reagan	2.5	6.0	+	2.5	3.0	+
Sign Test p-value			0.0039**			0.0039**

$^{**}p < 0.01$

who engaged in this improvement program were expected to ask more deflecting questions with the purpose of elongating and increasing student discussions during mathematics lessons.

In order to test this hypothesis, the math coach-researcher counted the number of deflecting questions the teachers asked before, during and after interventions during two 10-minute observation periods and compared the results using the one-tailed sign test. As shown in Table 5 there was a significant increase in the number of deflecting questions made after the third intervention in March which was when the teachers received coaching and practice in asking deflecting questions. Eight out of the eight teachers increased the number of deflecting questions after that specific intervention was made in March compared to the baseline data taken in December ($t(7) = 0.0039$, $p < 0.01$).

Hypothesis 6- The Effects of a Mathematics Discussion Improvement Program on Student Talk Time

It was hypothesized that after teachers participated in the mathematics discussion improvement program, students would exhibit more math talk time and a higher frequency of comments and responses compared to before their teacher had participated in the professional development with the math coach. Specifically it was expected that after teachers engaged in this improvement program, students in their classes would have increased talk time compared to their talk time before the interventions took place.

Table 5

A Comparison of the Mean Number of Deflecting Questions Used by Teachers Before and After the Interventions During Two 10-minute Observation Period Before and After the Intervention in March

	Baseline	March	+/-
Brandon	0.0	2.0	+
Jones	0.0	3.5	+
Logan	0.0	1.0	+
Smith	3.5	5.0	+
Rodriguez	2.0	4.5	+
Lewis	2.5	7.0	+
Pope	0.0	1.5	+
Reagan	1.0	5.0	+
Sign Test p-value			0.0039**

**$p < 0.01$

In order to test this hypothesis, the mean length of student talk time during two 10-minute observation periods before the intervention was compared to the length of student talk time in January, February, and March after the training took place. A one-tailed t-test and a stopwatch were used to record length of student talk time in minutes during each observation. As shown in Table 6, there was as significant increase in mean length of student talk time at all three points of observation following the teacher training. The mean student talk time increased from 2.33 minutes during the baseline to 3.14 minutes in January ($t(7) = 2.09$, $p < 0.05$) and to 2.95 minutes in February ($t(7) = 1.95$, $p < 0.05$ The largest increase occurred in March when the mean student talk time increased to 3.41 minutes ($t(7) = 4.50$, $p < 0.01$). Thus, these results supported the hypothesis that students would talk more during mathematics lessons after their teachers had participated in the mathematics discussion improvement program.

Hypothesis 7- The Effects of a Mathematics Discussion Improvement Program on Students' Unit Assessment Scores

It was hypothesized that after the teachers participated in the mathematics discussion improvement program, student would achieve higher scores in the unit assessments including short-answer and open-ended questions compared to before their teachers had participated in the professional development with the math coach-researcher. Specifically it was expected that after teachers engaged in this improvement program, students in their classes would have higher scores on unit

Table 6

A Comparison of the Mean Length of Student Talk Time in Minutes During Two 10-minute Observation Periods Before and After the Intervention in January, February, and March

	Baseline	January	t-score	Baseline	February	t-score	Baseline	March	t-score
Brandon	1.77	3.68		1.77	2.23		1.77	3.60	
Jones	2.10	2.43		2.10	4.27		2.10	3.23	
Logan	1.55	1.82		1.55	1.93		1.55	2.42	
Smith	2.87	4.93		2.87	3.25		2.87	4.13	
Rodriguez	3.23	5.43		3.23	3.20		3.23	3.10	
Lewis	2.58	2.25		2.58	4.30		2.58	3.35	
Pope	0.97	1.40		0.97	1.43		0.97	1.78	
Reagan	3.60	3.15		3.60	3.02		3.60	5.63	
Group Mean	2.33	3.14	2.09*	2.33	2.95	1.95*	2.33	3.41	4.50**

*$p < 0.05$

**$p < 0.01$

assessments compared to their scores on a similar unit assessed before the intervention began.

To test the hypothesis that students would perform better on unit assessments after their teachers were trained than before the teachers were trained, mean unit assessment scores for Unit 4, the unit learned prior to the intervention, were compared to scores on Units 5, 6, and 7, the units covered during and after the interventions. As shown in Table 8, overall, scores on Units 5, 6, and 7 were not greater than scores on the baseline unit. In January the group mean slightly increased from 78.28 to 80.39 ($t(7) = 0.41$, $p < 0.40$) which was not significant. In February the group mean decreased to 71.92 which was significant in the opposite direction ($t(7) = -1.43$, $p < 0.10$). In March the group mean virtually remained the same increasing slightly from 78.29 to78.76. However, it is interesting to note that the individual class means for 3 third grade teachers decreased significantly and increased significantly for 3 fourth grade teachers. These mixed results and inconsistency suggested there was no predicted effect. Thus, the hypothesis predicting that students would achieve higher unit scores after their teachers were trained on improved discussion techniques was not confirmed.

Additional Research Questions

In addition to the statistical results, informal observations of students and teachers participating in the interventions were also recorded and are reported on here. The math coach-researcher was interested in any particular

Table 7

A Comparison of the Mean Assessment Scores Before, During, and After Interventions

	Unit 4	Unit 5		Unit 4	Unit 6		Unit 4	Unit 7	
	Baseline	January	t-score	Baseline	February	t-score	Baseline	March	t-score
Brandon	77.00	81.05	0.67	77.00	81.33	0.78	77.00	84.76	1.41
Jones	84.39	82.74	-0.58	84.39	64.61	-5.99**	84.39	77.04	-1.99*
Logan	89.86	90	0.00	89.86	73.10	-8.10**	89.86	81.95	-2.97**
Smith	90.75	89.50	-0.51	90.75	75.50	-8.21**	90.75	82 13	-3.77**
Rodriguez	75.44	76.94	0.36	75.44	68.94	-1.70	75.44	81.53	2.23*
Lewis	73.21	75.29	0.26	73.21	60.52	-2.18*	73.21	73.64	0.02
Pope	78.96	86.46	2.64**	78.96	77.07	-0.58	78.96	83.79	1.46
Reagan	56.69	61.15	1.14	56.69	74.27	5.82**	56.69	65.23	3.02**
Group Mean	78.29	80.39	0.41	78.29	71.92	-1.43	78.29	78.76	0.1

*p < 0.05

**p < 0.1

behavioral patterns that were not accounted for in the formal data and whether or not there were any other factors that contributed to effective coaching and mathematics success. No particular predictions were made with regards to these additional questions. These observations were made on the same teachers who participated in the mathematics discussion improvement program and their students.

These observations revealed that even though teachers were able to increase their wait time after asking a mathematics questions, it did not necessarily follow that the students would always be able to answer the questions posed. Some students took advantage of the extra time by really trying to figure out how to answer the questions by quietly working at their desks or engaging in low conversations with their table group. Some students initially called out during the wait time trying to get the teacher's attention and disturbing the concentration of other students. Some students still were not engaged as evidenced by blank papers and off task behaviors such as doodling and staring into space. Other students were not able to make use of the extra time at all and, as evidenced by their responses, clearly did not understand the questions.

Informal observations by the math coach-researcher also revealed that even though many of the teachers were able to incorporate more open-ended questions, guiding statements and follow up questions, and deflecting questions in their mathematics lessons thereby potentially increasing student participation in discussions, the length and depth of individual student's comments did not really seem to increase. This was apparent in the third grade geometry unit where the questioning pursued by the teachers was only at Van Hieles' Level 1. What did appear to increase were the frequency of teacher to student questions rather than a deeper understanding of mathematical concepts. Even though teachers were asking more questions dealing with alternate methods and how students arrived at obtaining answers, the discussions oftentimes centered on procedures rather than on mathematical concepts. This was apparent in the fourth grade fraction unit where it was especially difficult for the students to describe fractional equivalents and fractional operations as general concepts rather than as specific examples.

The Teacher Questionnaire that was filled out after the three interventions and is contained in Appendix T. This questionnaire was scored on a 5-point Likert scale with 50 as the highest score possible Individual scores ranged from 26 to 41. It contained questions on teachers' attitudes and inclinations towards teaching mathematics, the amount of mathematics professional development they received, and their perception of their individual teaching practices. Information about the teachers' individual demographics such as the number of years teaching, their age, highest degree they held, and the number of years in the school district were also obtained.

The questionnaires were very interesting individually, but there weren't any relationships between the teachers' attitudes towards teaching mathematics and their positive responsiveness to the mathematics improvement program. Most of the teachers indicated that mathematics is one of their favorite subjects to teach and they would like to attend more professional development workshops in mathematics. In addition, most of the teachers also indicated that they felt they had ample discussion time in their mathematics classes and that they waited enough time after asking questions. All of the teachers indicated they wanted to attend more professional development programs in mathematics.

The informal results of the teacher questionnaire supported the research done by Schorr, Firestone, and Monfils (2003) where teachers' opinions about their observed practices are not always in agreement with researched observations. Teachers often believe that they are engaging in certain practices or have changed certain behaviors even though they have not truly adopted these behaviors when they are observed.

Summary of Results

Most of the predictions regarding teacher behaviors in this study were supported by the data collected. The hypothesis predicting that teachers would decrease their talk time after the training was partially supported. Teacher talk time was significantly decreased for the January observation compared to the baseline measure, but this decrease was not sustained for observations made in February and March. The hypothesis predicting that teachers would increase their wait time before calling upon students after the training was supported by threefourths of the teachers. Teacher wait time significantly increased after the first intervention compared to the baseline measure and was sustained for observations made in February and March. The hypothesis predicting that teachers would increase the number of open-ended questions after training was partially supported. The number of open-ended questions teachers asked was significantly increased for the January and March observations compared to the baseline measure, but this decrease was not sustained for the observation made in February. The hypothesis predicting that teachers would increase the number of guiding statements and follow-up questions after training was supported. The number of these types of questions increased significantly in February and March compared to the baseline data. Data for January were not compared because this intervention was introduced in February. The hypothesis predicting that teachers would increase the number of deflecting questions after training was supported. The number of this type of question increased significantly in March compared to the baseline data. Data for January and February were not compared because this intervention was introduced in March.

The predictions made regarding student behaviors in this study were only partially supported. The hypothesis predicting that student talk time would increase after training was supported after each intervention. Student talk time was significantly increased for the January intervention compared to baseline data and this increase was sustained for observations made during February and

March. The hypothesis predicting that unit test scores would increase after training was not supported. Unit test scores did not significantly increase after the January intervention compared to baseline data and did not increase in February and March as well.

Despite the lack of statistical confirmation on increasing student achievement, informal observations indicated that overall, students had a neutral to positive reaction to being asked to participate more during mathematics lessons. In many cases, students had difficulty in explaining their thoughts and methods of solving problems. In addition, even though teachers were able to incorporate better questioning techniques into their mathematics lessons, this did not necessarily lead to a richer discussion of mathematics.

Chapter V

Discussion

This study investigated the effects of a school-based mathematics coaching program on third and fourth grade urban teachers' facilitation of student mathematics talk. It was expected that after working with the math coach on this topic that teachers would change their behaviors during class discussions. It was also expected that as a consequence of these changes that students' participation in class discussions would also change and that their scores on unit tests would increase. Although most of the predictions regarding the teachers were confirmed, the student outcomes were not strongly affected. The following is a discussion of the possible reasons for the outcomes of each hypothesis followed by explorations of the educational implications of the research findings.

Hypothesis 1 – The Effects of Professional Development by a Math Coach on Teacher Talk Time

As expected, the amount of time that spent on teachers talking during mathematics lessons decreased as they practiced asking different types of questions to help elongate student discussions in their mathematics classes. The most significant decrease occurred after the first month of coaching and although teacher talk also decreased during the two subsequent months, the decrease compared to the pre-intervention measure was not statistically significant. All of the teachers decreased their talk time during at least one set of observation periods and three teachers decreased their talk time during all three interventions.

These results occurred for a variety of reasons. One reason is possibly because the teachers were able to focus on a few particular elements better at the beginning of the study when there were only a few elements introduced. At the middle and end there many techniques the teachers were trying to learn and the initial effect of decreasing teacher talk time wore off. In addition, some teachers voiced concerns during the research study that if they were continuing to ask additional questions, how were they supposed to decrease their talking time? Since many of the teachers had been accustomed to talking more when introducing lessons, they could have gone back to their old ways when concentrating on introducing more elements to their lessons.

In addition, there is the possibility that when the math coach researcher entered the classrooms for observations, the teachers reduced their amount of talking as a reaction to her presence. Then after they became accustomed to the idea of being part of the research study, they did not necessarily react to her presence as strongly because the power of the effect decreased over time

Hypothesis 2- The Effects of Professional Development by a Math Coach on Teacher Wait Time

As expected, teacher's wait time prior to calling on students or asking another question increased significantly after participating in the training program. The most significant increase occurred after the first month of coaching and was significantly sustained during the subsequent 2 months. All of the teachers increased their mean wait time individually and 7 out of 8 of those individual increases were statistically significant. In the case of the single teacher who did not increase her wait time, it is interesting to note that her baseline wait time was more than 50% above all of the other baseline wait times and her post-observation wait times were also greater than most of the other teachers' post-observation wait times.

Since the first intervention the math coach researcher made had to do with increasing teacher wait time, decreasing teacher talk time, and increasing open-ended questioning, the impact of this initial element could have had the most impact because it was at the outset of the research. Again as the research got underway, the power of the initial effect decreased over time.

Hypothesis 3- The Effects of Professional Development by a Math Coach on Teachers' Open-Ended Questions

As expected, the amount of open-ended questions that teachers asked significantly increased after participating in the mathematics discussion program. The most significant increase occurred after the first month of coaching, then still increased, but not significantly, after the second month of coaching, and again increased significantly after the third month of coaching. All of the teachers increased the number of open-ended questions posed after the first month when specific coaching was given on this type of questioning.

Asking open-ended questions was relatively easy if practiced because questions were reframed in a how or why format. Asking open-ended questions was more of a procedure than a skill because it did not require deep understanding of mathematics. What did require a deeper understanding of mathematics were the guiding statements, follow-up questions, and deflecting questions.

Most students had to build on each others' responses to arrive at acceptable explanations and were not usually able to do this individually. In order to be effective, these responses were prompted by teachers' open-ended questions to uncover the mathematical concepts, not just procedures. If students had also been retrained in this study on discussions techniques, there may have been lengthier student responses and more frequent student to student comments rather than more teacher to student questions.

Hypothesis 4 – The Effects of Professional Development by a Math Coach on Teachers' Guiding Statements and Follow-up Questions

As expected, teachers were able to increase the number of guiding statements and follow-up questions after participating in the mathematics discussion program. This intervention was made after the second month of coaching and significant increases were sustained after the subsequent two months. In addition all of the teachers individually increased the number of guiding statements and follow-up questions during the two months following this intervention.

Teachers who thought beyond the initial questions were more successful in exposing students' thinking. This present research supported their findings in that teachers were able to be trained to ask more questions and different types of questions to elicit more student discussion. A study by Franke, Webb, Chan, Battey, Ing, Freund, and De (2007) explored the teacher practice of questioning in order to encourage student elaboration. Their key finding was that in order for follow-up questions to be most effective, these questions needed to be planned out in advance. The mere act of asking additional questions was only sometimes helpful in sometimes revealing students' thinking.

As confirmed in this research study, just asking more questions increased the incidence of responses, but not necessarily the length and quality of those responses. There were also other factors involved such as the high proportion of English Language Learners in the school. In addition, this was only the third year of using a reform mathematics curriculum and the second year there was a school-based math coach.

Hypothesis 5 – The Effects of Professional Development by a Math Coach on Teachers' Deflecting Questions

As expected, the number of deflecting questions that teachers asked after participating in the mathematics discussion program increased significantly. This intervention was made during the third month of training and the increase was made by all of the teachers in the program.

Asking deflecting questions required the teacher to plan some of the questions as well as to understand the student's reference point. Teachers were successful in increasing their frequency of questions, but the sequence of questioning was not always the best especially if the questions were not planned out or anticipated. Planning out the questions required more time, thought and experience with reform mathematics. The procedure of asking more deflecting questions was followed by teachers, but this did not always help with the conceptual development of the students possibly due to the mathematics ability of the individual teacher.

The quality of the teachers' questioning affected the quality of the students' responses. This present research was able to increase the amount of successive questioning in order to obtain more student discussions in the mathematics classrooms which was also confirmed by Franke, Webb, Chan, Battey, Ing, Freund, and De (2007).

Hypothesis 6- The Effects of Professional Development by a Math Coach on Student Talk Time

As expected, the amount of student talk time increased significantly after the mathematics discussion program. Significant increases were observed during all three months of intervention with the most significant increase after the third month of coaching. All of the teachers had at least one significant increase in student talk time during the program, and this result follows in that if the teachers were successful in asking more questions of the students, then the students would take more time to answer more questions.

An interesting observation was that there was still a considerable amount of time when neither the students nor the teachers were talking. And just because a teacher was talking less did not necessarily mean the students would talk more. While this present study did not focus on the abilities of the student participants; there were students who participated minimally or did not participate in discussions because of their limited understanding, but were exposed to the higher level thinking of their peers. This present study was also able to expose some additional student thinking and increase participation by sensitizing the teachers to build on students' responses rather than dismissing incorrect or incomplete responses.

Hypothesis 7- The Effects of Professional Development by a Math Coach on Student Unit Assessment Scores

Contrary to expectations, student unit assessment scores did not increase after the mathematics training program. In fact, the mean scores were relatively flat after the first and third months of mathematics coaching, and the scores decreased after the second month. None of these changes were significant when comparing the mean scores, however there were significant increases and decreases in some classrooms. The most significant decrease in assessment scores occurred in the third grade Unit 6 which was on geometry; the mathematics topic that most of the teachers indicated was the most challenging and least favorite to them personally.

The effect that the professional development had on student achievement was not validated for a variety of reasons. First of all, the students in this setting, with few exceptions, had been conditioned to listen and not speak until this point in their education. It is very difficult to change 4 to 5 years of strict listening behaviors without having the students retrained as well. Students did improve in their discussion techniques, participation and explanations, but this did not translate into higher unit assessment scores.

The study conducted by Hufferd-Ackles, Fuson, and Sherin (2007) followed one urban Latino classroom shift throughout the course of the year to a math talk learning community where students assisted each others' learning through mathematical discussions. The class moved through different defined levels of student and teacher participation which propelled the students into becoming responsible for their own learning. This present study supported these findings in that the first phase of development took approximately 8 weeks. This first phase cemented the role of students in explaining their thinking before developing further and having students becoming both co-teachers and co-learners. The latter stages were not observed due to the shorter length of this study

Additional Findings

Informal observations offered additional insight on the effect of a school-based math coaching program on teachers' facilitation of student math talk. For the most part, teachers were able to increase their wait time and many students were able to make use of this additional time to think about how to respond to a question. When students did not respond, some teachers rephrased the question, some called on other students, and some eventually answered the questions themselves. Initially, students did not expect to be called on because many teachers previously would have given the answers themselves after only one incorrect response. As the study progressed, more students were participating in answering questions and there were more discussion questions for them to answer. Some of the teachers expressed hesitation in the beginning of the study in terms of spending too much time asking questions instead of modeling solutions in front of the students. Even with this mindset, teachers were still able to show changes in how they asked questions during mathematics lessons.

There were certain classroom management techniques the math coach-researcher observed which enabled more student participation in classroom discussions. Classrooms where teachers rewarded participation by giving out points to groups that participated in answering questions had much more discussion and engagement by the students. These classrooms were typically more animated and lively partially due to the excitement of receiving reward points. Another technique observed was that teachers who allowed students to save face by not announcing that the student's answer was incorrect typically had more students participating and engaged in discussions than other classrooms.

The math coach-researcher found that all of the teachers in this study were very responsive to this professional development program despite their personal feelings about teaching mathematics. In fact, most of the teachers indicated that mathematics was one of their favorite subjects to teach even though most of the teachers were not satisfied with the present reform mathematics series. The math coach-researcher also noted that just because a teacher says she enjoys teaching mathematics, it does not necessarily follow that those teachers would ask different kinds of questions than those teachers who did not enjoy mathematics. The teacher's ability to ask more involved questions appeared to be related to the teacher's understanding of the mathematics subtopic and her ability to value different approaches to solving mathematics problems.

Also of note was that if a particular student was unable to respond, solely giving him or her additional time would not usually enable him or her to provide an answer to a question. Obtaining multiple students' responses and building on them in succession appeared to increase the length, depth, and amount of students' comments and questions. In addition, students initially were not accustomed to explain how they figured out an answer or were they accustomed to explain multiple approaches in solving a problem. Students' reactions to having more questions posed to them varied across the spectrum. Generally many students who had previously not participated, were now participating more in mathematics discussions.

Conclusions

In general this study indicates that with regular coaching sessions from a school-based math coach, that teachers were able to alter their teaching practices. The magnitude of individual teachers' changes varied with little relationship to their personal attitudes towards reform mathematics or mathematics in general. The fact that the students' assessment scores did not significantly increase during the study can be related to some of the constraints of the study.

The type of professional development the math coach-researcher used in this study was very specific and of relatively short duration. In reviewing some of the aspects which could have been better designed, there were several areas which could have been improved upon.

The scope of this study was very broad and if narrowed, could yield more specific findings which could be useful. The focus had many facets which were intertwined in an immeasurable way yet were not causal. For example, the 10 minute observation times were broken down between teacher talk and student talk, however, the two times did not add up to 10 minutes. There were sometimes other things going on such as students working silently.

Some of the questions brought up during Grade Level Meetings were very valuable in exposing some of the limitations in this study. One topic was the perceived inconsistency in expecting teachers to talk less if they are expected to ask more frequent and involved questions. Another area was what to do during the additional wait time if students were not taking advantage of the time to further develop their conceptual understanding. Initially teachers were not sure they would have the time to ask more questions because they were concerned about covering the topics in the lessons. Having open honest discussions at the Grade Level meetings reinforced some of the ways in which the individual teachers were handling the changes in their practices.

In retrospect, there are several areas of this study which, if changed, might yield in more useful results. There were several problems with the Unit Assessments that were used. The Unit Assessment used as a comparative benchmark in December was not the same level of difficulty as later Unit Assessments. A major problem was that they contained a variety of information and were not pre-tested by topic. In addition, there was only one open-ended question on each Unit Assessment which weren't always understood by the teachers as well as the students.

The timing of the math coach-researcher's observations also could have been modified. Because of the rather large sample of 8 teachers, classroom observations were only 10 minutes in duration and were not always at the most appropriate time during the mathematics lessons. In addition, concentrating on 2 different grade levels teaching different topics with different materials, made the researchers' observations more challenging.

Significant improvements in the detail of the research would be achieved if the researcher's observations were audio-taped or videotaped. The manual recording of observations was very cumbersome as was the measurement of times. Having a recording would enable the researcher to go back and obtain more detailed results on the interventions and observations.

The bi-weekly scheduling and half-hour duration of the Grade Level Meetings was a limiting factor in teacher-to-teacher collaboration. There were very useful and revealing discussions that took place during these meetings which could be acted upon more constructively if they were of longer duration.

The positive response and results from all of the teachers showed that short-term focused professional development can have desired outcomes despite individual differences and styles. To achieve more sustained changes, the students could also be involved and made aware of increased expectations on them. Students clearly were not accustomed to revealing their thoughts and extending their discussions. To achieve more widespread results, parents could also be informed of the increased expectations in student discussions.

Educational Implications

In general, this study supports the effectiveness and impact of a school-based math coaching program. This type of professional development, though not a new invention, has been researched minimally despite the increasing numbers of math coach positions that have been created in the past 10 years. The role of the school-based math coach is open to interpretation and differs across school districts. Maintaining confidentiality, trust, and respect between grade levels, individual teachers, the math coach, and the administrators is a delicate balance. If the confidentiality is not maintained, the program may not work effectively because of fear of retaliation or disciplinary action.

Overall, this study demonstrated that changes in teachers' behaviors and practices can be achieved with a focused school-based math coaching program. In order to be more effective, the interventions should be longer and more individualized. Just as a one-size-fits-all education for students is not acceptable, there needs to be a way to better differentiate professional development through the math coaching program. This study attempted to meet the individual needs of the teachers through individual conferencing and feedback. Mapping out individual progress and changes during more frequent discussions between teachers and the math coach would improve results. The logistics of these discussions is very challenging because of the limitations of schedules and the requirements of student contact times.

In addition, a more encompassing approach to coaching could make a stronger impact. By increasing the frequency and duration of both coaching and professional development sessions, the overall impact of math coaching should increase. A focused after school mathematics program with weekly meetings after school could be a starting point to achieve several changes such as teachers' mathematics content knowledge, teachers' collaboration and sharing successes, and teachers' comfort level with reform mathematics areas.

By combining this with regular Grade Level Meetings and in-class coaching sessions, the contact between and amongst teachers and coaches would increase and assist in obtaining mastery of mathematics topics and changes in teaching styles. The shift from a traditional to reform style requires determination and the desire to change on the part of the individual educators.

Overall this study demonstrated the positive effects of a school-based math coaching program in an urban setting. If a more comprehensive, regular and long term set of professional development experiences were created to increase both teacher and student involvement in mathematics, long term improvements in students' achievement could result.

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APPENDIX C

SAMPLE NOTETAKING FORMAT

Research Question	Variables	Evidence/Data Observations
What do the students do when the teacher…..	Conversation of students	
…..gives additional wait time for the students to answer a question?	Teacher pauses	
	Teacher asks question	
…….or responds with a follow-up or guiding statement?	Student(s) answer question	
……..or asks deflecting questions?	Affect and engagement	
	Other	
	Type of questions	

Appendix H

Math Grade Level Meeting Agenda (#1)
Grade 3
January 14, 2009
Wednesday – Period 11

- **Introduce the target skill for the next two weeks:**
  Increasing wait time & asking more open-ended questions
- **Practice these skills**
- **Role Play using these skills**
- **Questions????**

In attendance:

1.	**4.**	**7.**
2.	**5.**	**8.**
3.	**6.**	**9**

Appendix I

Math Grade Level Meeting Agenda (#2)
Grade 3
January 28, 2009
Wednesday – Period 11

- **Discuss the target skill used during the past two weeks:**
  Increasing wait time & asking more open-ended questions

- **Successes**

- **Challenges**

- **Questions????**

In attendance:

1.	4.	7.
2.	5.	8.
3.	6.	9.

Appendix J

Math Grade Level Meeting Agenda (#3)
Grade 3
February 11, 2009
Wednesday – Period 11

- **Introduce the target skill for the next two weeks:**
  Responding with follow-up and guiding statements to students' initial responses

- **Practice these skills**

- **Role Play using these skills**

- **Questions????**

In attendance:

1.	**4.**	**7.**
2.	**5.**	**8.**
3.	**6.**	**9.**

Appendix K

Math Grade Level Meeting Agenda (#4)
Grade 3
February 25, 2009
Wednesday – Period 11

- **Discuss the target skills used during the past two weeks:**
  Responding with follow-up and guiding statements to students' initial responses

- **Successes**

- **Challenges**

- **Questions????**

In attendance:

1.	**4.**	**7.**
2.	**5.**	**8.**
3.	**6.**	**9**

Appendix L

Math Grade Level Meeting Agenda (#5)
Grade 3
March 11, 2009
Wednesday – Period 11

- **Introduce the target skill for the next two weeks:**
  Making deflecting statements and additional questions to elongate students' responses

- **Practice these skills**

- **Role Play using these skills**

- **Questions????**

In attendance:

1.	**4.**	**7.**
2.	**5.**	**8.**
3.	**6.**	**9.**

Appendix M

Math Grade Level Meeting Agenda (#6)
Grade 3
March 25, 2009
Wednesday – Period 11

- **Discuss the target skills used during the past two weeks:**
  Making deflecting statements and asking additional questions to elongate students' responses

- **Successes**

- **Challenges**

- **Questions????**

In attendance:

1.	**4.**	**7.**
2.	**5.**	**8.**
3.	**6.**	**9.**

Appendix N

Math Grade Level Meeting Agenda (#1)
Grade 4
January 13, 2009
Tuesday – Period 11

- **Introduce the target skill for the next two weeks:**
  Increasing wait time & asking more open-ended questions

- **Practice these skills**

- **Role Play using these skills**

- **Questions????**

In attendance:

1.	**4.**	**7.**
2.	**5.**	**8.**
3.	**6.**	**9.**

Appendix O

Math Grade Level Meeting Agenda (#2)
Grade 4
January 27, 2009
Tuesday – Period 11

- **Discuss the target skills used during the past two weeks:**
  Increasing wait time & asking more open-ended questions

- **Successes**

- **Challenges**

- **Questions????**

In attendance:

1.	**4.**	**7.**
2.	**5.**	**8.**
3.	**6.**	**9.**

Appendix P

Math Grade Level Meeting Agenda (#3)
Grade 4
February 10, 2009
Tuesday – Period 11

- **Introduce the target skill for the next two weeks:**
  Responding with follow-up and guiding statements to students' initial responses

- **Practice these skills**

- **Role Play using these skills**

- **Questions????**

In attendance:

1.	**4.**	**7.**
2.	**5.**	**8.**
3.	**6.**	**9.**

Appendix Q

Math Grade Level Meeting Agenda (#4)
Grade 4
February 24, 2009
Tuesday – Period 11

- **Discuss the target skills used during the past two weeks:**
  Responding with follow-up and guiding statements to students' initial responses

- **Successes**

- **Challenges**

- **Questions????**

In attendance:

1.	**4.**	**7.**
2.	**5.**	**8.**
3.	**6.**	**9.**

Appendix R

Math Grade Level Meeting Agenda (#5)
Grade 4
March 10, 2009
Tuesday – Period 11

- **Introduce the target skill for the next two weeks:**
  Making deflecting statements and additional questions to elongate students' responses

- **Practice these skills**

- **Role Play using these skills**

- **Questions????**

In attendance:

1.	**4.**	**7.**
2.	**5.**	**8.**
3.	**6.**	**9.**

Appendix S

Math Grade Level Meeting Agenda (#6)
Grade 4
March 24, 2009
Tuesday – Period 11

- **Discuss the target skills used during the past two weeks:**
  Making deflecting statements and asking additional questions to elongate students' responses
- **Successes**
- **Challenges**
- **Questions????**

In attendance:

1.	**4.**	**7.**
2.	**5.**	**8.**
3.	**6.**	**9.**

APPENDIX T

TEACHER QUESTIONNAIRE

5-Strongly Agree 4-Agree 3-Somewhat Agree 2–Disagree 1-Strongly Disagree

		5	4	3	2	1
1.	Math is one of my favorite subjects to teach.					
2.	I am satisfied with the present mathematics text.					
3.	The mathematics textbook is my main teaching aid.					
4.	The teacher's edition gives me adequate suggestions for Teaching a lesson					
5.	I have had ample professional development To teach *Everyday Mathematics*					
6.	I give my students enough time to discuss mathematics problems during math class					
7.	I pose a sufficient amount of open-ended questions during math class to generate student discussion					
8.	I wait enough time after asking a question to get students to respond.					
9.	I don't give away the answer with my body language or with facial expressions.					
10.	I would like to attend professional development workshops in mathematics.					

The information below is strictly confidential and optional.

years teaching this grade______

years teaching other grades_____ Please specify grades: ____________

years in this School District______

Age_____

Highest degree held ________

APPENDIX W

RESEARCH STUDY OUTLINE

TIMING	INTERVENTION
Week 0	Pre-Intervention of baseline observations on teachers and Unit assessments for students
Week 1	Grade Level Meeting #1 Introduced longer wait time and open-ended questioning
Week 1and 2	Classroom coaching
Week 3	Grade Level Meeting #2 Share teaching experiences on wait time and open-ended questioning
Week 3 and 4	Observations on teachers and Unit assessments for students
Week 5	Grade Level Meeting #3 Introduced follow-up and guiding statements to students' responses
Week 5 and 6	Classroom coaching
Week 7	Grade Level Meeting #4 Share teaching experiences on follow-up and guiding statements
Week 7 and 8	Observations on teachers and Unit assessments for students
Week 9	Grade Level Meeting #5 Introduced deflecting statements and questioning to students' responses
Week 9 and 10	Classroom coaching
Week 11	Grade Level Meeting #6 Share teaching experiences on deflecting statements and questioning
Week 11 and 12	Post-Intervention of observations on teachers and Unit assessments for students