

## ABSTRACT

THOMAS, SHAYLA M. Implementing Reform-Based Mathematics Instruction After Participating in Professional Development: Two High School Teachers' Experiences. (Under the direction of Drs. Robert Serow and Jere Confrey.)

Research has consistently shown simply adopting a new mathematics textbook as a catalyst for changing what occurs in mathematics classrooms will not necessarily result in the desired increases in student achievement, nor will it result in automatic changes in teachers' instructional practices. As teachers make the transition to teaching with reform-oriented curricula such as *Core-Plus*, they will need support and professional development. Learning to find the balance will take teachers time during which they will need to increase their familiarity with the curriculum and become more comfortable with what student behavior resembles in a student-centered environment. Further exploration is needed into the types of professional development that help teachers most when teaching with these curricula.

The two teachers who participated in this study participated in the NCIM professional development project, which took an innovative approach to professional development by creating an experience through which teachers would receive training in both the content of the curriculum and the pedagogical techniques needed to teach with the curriculum as well as follow-up visits throughout the school year.

This study explored the benefits of the professional development to the teachers, as well as any challenges the teachers encountered even after participating in the professional development activities. This study also explored how two teachers attempted to develop a mathematics discourse community in their classrooms. Creating a discourse community was a major focus of the NCIM Summer Institute.

Findings from the study indicate that the teachers struggled in several areas the semester following their participation in the NCIM Summer Institute. These areas included adjusting to the curriculum, managing student collaborative activities, timing and pacing the course material, incorporating technology tools, and facilitating discourse. While learning to facilitate the mathematical discourse associated with reform-oriented teaching was a struggle for the teachers, results from the study show that they were able to make progress within a semester. Both teachers were aware that they needed to improve their questioning techniques and strengthen their efforts to encourage and elicit student thinking. These results demonstrate the potential professional development activities associated with the NCIM project have for helping teachers transition to teaching with *Core-Plus*.

Implementing Reform-Based Mathematics Instruction After Participating in Professional  
Development: Two High School Teachers' Experiences

by  
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A dissertation submitted to the Graduate Faculty of  
North Carolina State University  
in partial fulfillment of the  
requirements for the degree of  
Doctor of Philosophy

Educational Research and Policy Analysis

Raleigh, North Carolina

2011

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**DEDICATION**

To my parents

## **BIOGRAPHY**

Shayla Mina Thomas was born in Brunswick, GA to Michael and Nagene Thomas. She has two younger sisters, Khaleh and Brea, and an older sister and brother, Sharonda and Dwayne. Shayla grew up in Brunswick, GA, a small town on the coast, and graduated from Brunswick High School in Brunswick, GA. She attended the all-women's Agnes Scott College in Decatur, GA, where she earned a Bachelor of Arts degree in mathematics.

During her final semester in college, Shayla participated in the McMurry Fellowship (sponsored by The Education Group) through which she was introduced to the world of independent schools. After she graduated, she moved to Houston, TX to teach middle school mathematics at an independent school. Three years later, she decided to pursue doctoral studies full-time and enrolled in the Educational Research and Policy Analysis program at North Carolina State University (NCSU) in Raleigh, NC.

She worked as a graduate research assistant on various projects while at NCSU, with the most recent being the North Carolina Integrated Mathematics (NCIM) Project, also the basis of her dissertation study.

## ACKNOWLEDGMENTS

The co-chairs of my dissertation committee, Dr. Robert Serow and Dr. Jere Confrey, deserve my sincere appreciation. I appreciate Dr. Serow's support and encouragement throughout my graduate studies. I thank Dr. Confrey for extending such an amazing opportunity to become a part of the NCIM project's research and evaluation team. I also thank her for her time, for her thoughtful feedback on every draft of this paper and throughout the study, and for pushing me to think differently.

I also thank committee members, Dr. Bonnie Fusarelli and Dr. Paul Bitting; members of the NCIM project team, Dr. Alan Maloney, Erin Krupa, and Drew Corley; the NCIM project directors, Dot Doyle and Helen Compton; and the teachers and students who participated in the study.

I thank the many friends, family members, and church members who supported me during my entire graduate school experience. I am especially grateful to my parents and sisters; colleague and friend, Wayne Lewis; and dear friend, Marrielle Myers.

Finally, I thank God for giving me the strength to accomplish this task and for such amazing people to help me along the way.

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## **CHAPTER ONE**

### **INTRODUCTION**

Within this era of high-stakes and accountability, school officials are interested in improving the knowledge and skills of U.S. students more than ever. According to international testing results, U.S. students' performance in mathematics lags students' performance in other countries, and concern is growing that U.S. students are inadequately prepared for college, the workplace, and daily life in general (Schmidt, Rotberg, & Siegel, 2003). For this reason, there has been great interest in improving the mathematics experiences of all U.S. students. Comparisons between U.S. students and students from other countries have intensified concern about the inadequacy in the knowledge and skills of U.S. students. U.S. 15-year olds scored below students in twenty-six countries that participated in a 2003 administration of the Program for International Student Assessment (PISA), which assesses students' ability to solve applied real-world problems (National Academy of Sciences, 2005). In addition, there is increasing national concern with high school dropout rates because increasing numbers of high school dropouts decrease the nation's competitiveness. High schools in North Carolina recorded dropout rates of 5.04%, 5.24%, 4.97%, and 4.27% in ninth through twelfth grades during the 2005-2006, 2006-2007, 2007-2008, and 2008-2009 academic years, respectively. This is approximately 20,000 students each year (North Carolina Department of Public Instruction, 2006; 2007; 2008; 2009).

The mathematics curricula used in U.S. schools have been blamed for the disparity between U.S. students and students with higher performance in other countries. The complaint has been that mathematics curricula used in U.S. schools have not been successful

in engaging students in problem solving and should include more applications, statistics, probability, and the use of computers as opposed to rote memorization (Thompson & Senk, 2003). This sentiment prompted the National Science Foundation (NSF) to invest \$93 million in the development of mathematics curricula that have been designed to support an instructional approach and classroom environment in which students solve problems in real-life contexts and focused on students' sense-making in mathematics (Lloyd, Remillard, & Herbel-Eisenmann, 2009; Schoen, Finn, Griffin, Field, & Fi, 2001; Senk & Thompson, 2003). These curricula have been designed with characteristics of the *Curriculum and Evaluation Standards for School Mathematics* (referred to as *Standards*) in 1989 by National Council of Teachers of Mathematics (NCTM) in mind and are commonly referred to a *Standards-based*, NSF-funded (NSF), reform, or integrated mathematics curricula.

The NSF curricula are designed to provide an alternative to the siloed course design of Algebra I, Geometry, Algebra II and Precalculus. Because reform-oriented curricula embody the tenets of the NCTM reform documents, they present mathematics differently than traditional mathematics curricula. The difference lies in the approach to student learning. A distinguishing characteristic of reform-oriented curricula is an emphasis on inquiry mathematics: students explore real-world mathematical situations within problem-centered activities. Reform-oriented curricula also emphasize mathematical thinking and reasoning, conceptual understanding, and problem solving in realistic contexts versus instead of on procedural fluency (Lloyd et al., 2009).

The curriculum of focus in this dissertation study is the high school curriculum, *Core-Plus Mathematics: Contemporary Mathematics in Context* (Coxford et al., 1997-2001)

developed by the Core-Plus Mathematics Project (CPMP). Much of the data on *Core-Plus* was collected during the field-testing of the curriculum, and results have generally shown that students in *Core-Plus* classrooms perform at least as well as students in traditional curricula in all areas except procedural fluency (Schoen & Hirsch, 2003b). Data have revealed that *Core-Plus* students perform especially well in the areas of understanding, reasoning, and problem solving, and tasks involving statistics and probability, which are concepts emphasized throughout *Core-Plus* (Schoen, Hirsch, & Ziebarth, 1998; Schoen & Hirsch, 2003a, 2003b; Schoen & Pritchett, 1998).

As schools continue to adopt *Core-Plus*, the body of research on the curriculum's effectiveness continues to grow, but there are conflicting results and conclusions. In fact, one could ask whether we can even compare a new approach to learning mathematics such as the reform-oriented curricula to a traditional approach when reform curricula require such an adjustment for both teachers and students. Still, school decision makers are looking to researchers to provide evidence that these curricula actually help increase student achievement as they look for ways to improve student achievement (Schoenfeld, 2002; Lloyd, et al., 2009).

Research studies have consistently shown that just selecting a new mathematics curriculum will not ensure that students will learn the material (Porter, 2002; Stein, Remillard, & Smith, 2007; Stein, 2007). More important, is how the curriculum is implemented. An assumption of much of education reform in mathematics curricula is that teachers and schools are implementing the curricula appropriately and that students are provided the opportunity to learn in the ways aligned with the authors' intentions (Porter,

2002). Several evaluative studies of *Core-Plus* have compared it to traditional curricula (Schoen et al., 1998; Schoen & Hirsch, 2003a, 2003b; Schoen & Pritchett, 1998), but have done so without attending to the extent to which the curriculum was implemented also referred to as treatment fidelity or implementation fidelity. As a result, the findings from some studies are difficult to interpret, and it is challenging to draw conclusions about which curriculum might be better for the students. The fairness of comparing students' performance and declaring that a curriculum has not served them well without making certain (or at least acknowledging) that the curriculum may have been improperly implemented is problematic. Furthermore, documenting implementation and comparing curricula based on the documentation is still inadequate because teachers as the mediators between the curriculum and the students determine what content students are provided an opportunity to learn (Porter, 2002). If the goal is truly to make an impact on student achievement, then greater attention should be placed on how teachers implement the curriculum and the experiences students are likely to have as a result.

Since teachers are often the mediators between the curriculum and the content students are exposed to, it is also important to focus on the role of the teacher in the *Core-Plus* classroom. Disparities in implementation exist because teaching with a reform-oriented curriculum is a new experience for most teachers, and there is a considerable adjustment period. During this adjustment period, some teachers have been found to supplement the curriculum with traditional materials, further complicating the comparison of the two curriculum types. Tarr and his colleagues (2008) have conducted a number of studies examining implementation of *Core-Plus*, and have argued that because of disparities in how

teachers will enact the curriculum, researchers should document fidelity of implementation if they will attempt to establish a link between curriculum type and student achievement. This means that researchers must consider how the textbooks are being used in the classrooms and pay particular attention to how to consider the variability in implementation when considering the results of the studies.

With implementation of the curriculum as a concern, professional development is seen as a way to help teachers implement *Core-Plus* effectively. This dissertation study examines teachers' experiences teaching with *Core-Plus* after they participated in a professional development intervention designed to help them implement the curriculum.

### **Research Focus**

More and more, mathematical knowledge is becoming the bridge between the “haves” and “have nots” in society, that mathematical literacy is what grants traditionally left-out students access to economic success. Because mathematical knowledge is viewed as a vehicle for social mobility, changing the ways children learn mathematics has become a pressing concern especially for people who view education as a means to challenge the status quo and ensure social mobility rather than prepare economically disadvantaged students to assume their predetermined statuses in society (Schoenfeld, 2004).

The “math wars” has often been used to describe the tensions between two camps of individuals concerned with mathematics education – advocates of keeping mathematics education as it was and advocates of reform mathematics (Schoenfeld, 2004). The 1983 report, *A Nation at Risk*, spawned close attention to the disparities between the U.S. and Asian countries, and since then the focus on raising U.S. students' achievement has been



intense. Now with the focus on high-stakes testing and accountability intensified by the 2002 reauthorization of the Elementary and Secondary Education Act (ESEA) also referred to as the No Child Left Behind Act (NCLB, 2002), school officials are under pressure to raise student achievement and are concerned with improving mathematics education more than ever. Some school officials view adoption of a mathematics curriculum as a catalyst to improve the mathematics knowledge and skills of their students. In fact, many school districts have attacked the challenge of raising student achievement by mandating the adoption of a single curricular program at each level or subject area (Archer, 2005). Due to NSF efforts and the focus on improving the mathematics experiences of U.S. students, districts have more curricula to choose from than in the past four decades (Tarr et al., 2008).

While there was controversy around making students prepared for mathematics-related careers, the concern is no longer just with increasing the mathematical skills of the students attending college, but that the general public also needs increased mathematics skills (Schoen & Hirsch, 2002). Reform-oriented curricula show potential in addressing this issue because of their focus on problem solving in real-world contexts. School officials and researchers are interested in how these new curricula affect student learning, but trying to draw a direct link between the textbooks students use and the mathematics they actually learn is a complex task despite the major role textbooks play in determining what constitutes the mathematical experiences of students (Tarr et al., 2008). Several factors in addition to choice of curriculum mediate student learning. These include teachers' choices and actions, school and classroom organization, and students' preparation and motivation for learning. It is not as

simple as comparing the test scores of students in traditional curricular paths to those in *Core-Plus*.

Studies exploring the experiences of teachers implementing reform-oriented curricula (Arbaugh, Lannin, Jones, & Park-Rogers, 2006; Kazemi & Stipek, 2001; Lloyd, 1999, 2002; Wilson & Lloyd, 2000; Ziebarth, 2003) have found that the transition from teaching with traditional mathematics curricula is challenging for teachers. For many teachers, NSF curricula are outside their familiar realm, both in content and in form (Lloyd et al., 2009; Nathan & Knuth, 2003). Reform instruction in any subject area requires teachers to make shifts. Making the shift is challenging, because typically teachers do not have experience teaching in or being a student in a reform classroom (Darling-Hammond & McLaughlin, 1995).

In particular, teachers using *Core-Plus* expressed discomfort in trying to finding the balance between teacher direction and student independence called for by the curriculum, sometimes also having difficulty accepting that their students were able to make important connections without a direct explanation from them (Wilson & Lloyd, 2000). A small body of research has examined the instructional practices and mathematical conceptions of teachers implementing *Core-Plus* (Arbaugh et al., 2006; Lloyd & Wilson, 1998; Wilson & Lloyd, 2000). Teacher beliefs, experience, and understanding of mathematics all have been found to influence teachers' pedagogical decisions (Lloyd, 1999; Lloyd et al., 2009).

If teachers become frustrated when adjusting to reform mathematics instruction and the curricula, they may alter their instruction, resulting in a decrease in the cognitive demand of tasks or they simply abandon reform teaching practices altogether for traditional

instructional practices (Darling-Hammond & McLaughlin, 1995). Teachers may find themselves in the unfamiliar position of trying to strike an appropriate balance between providing too much information for students and allowing students to struggle with mathematical concepts. Teachers may also struggle with transferring authority to their students for their learning without the tasks (or investigations in *Core-Plus*) going down unintended paths and possibly resulting in a meaningless experience for students. Essentially, teachers will need time to find the balance.

Switching to a curriculum like *Core-Plus* can be especially tough for some teachers who are unable to separate their conceptions of mathematical content from their conceptions about how the mathematics should be taught. This process starts with becoming more comfortable with the curriculum and more comfortable with what student behavior resembles in a student-centered environment (Lloyd & Wilson, 1998). Helping teachers implement these curricula should be a priority, especially if the real interest is in making credible examinations of effectiveness and comparisons between curricula. Because implementation of the curriculum is essential to learning about student outcomes, support mechanisms should be provided to aid in the transition for teachers if the goal is to increase student achievement.

So how are teachers expected to transform their teaching? A common theme throughout the research on teaching reform mathematics curricula is that teachers implementing reform mathematics curricula will need professional development to assist with the transition (Darling-Hammond & McLaughlin, 1995; Lloyd, 1999; Schoen & Hirsch, 2003b; Ziebarth, 2001.) What supports do teachers need and which will be most beneficial? There is still much to learn about what types of professional development models are most

effective in helping teachers make the transition, while also increasing their knowledge and skills, and changing teacher practice. In addition, we stand to learn more about how teachers respond to various professional development models in general.

The underlying theory of action of most professional development activities is that teachers will participate in professional development activities designed to promote a change in instructional practices, and the expectation is that the teachers would implement the ideas presented. Then one would look for changes, with an expectation or at least anticipation of improvements in student performance. Recent work (Tarr et al., 2010) on implementation issues and *Core-Plus* has shown that there is impact from other factors. In light of these findings, it is unreasonable to expect changes in student outcomes solely based on teachers' participation in professional development, because there is more at play.

### **The North Carolina Integrated Mathematics (NCIM) Professional Development Model**

Teachers included in this study participated in a professional development model (the North Carolina Integrated Mathematics project) designed to support teachers in North Carolina implementing *Core-Plus*. NCIM was developed and designed in collaboration with the North Carolina New Schools Project (NCNSP) and North Carolina State University (NCSU) through a NC-STEM Mathematics Science Partnership Grant from North Carolina Department of Public Instruction (NCDPI). The components of NCIM included a As part of the grant, teachers at seven NC-STEM partner schools received follow-up content specialist visits mentioned above. The inclusion of content specialist visits is a difference between NCIM and other professional models. Most of the partner schools involved in this project are located in rural areas of North Carolina and were identified as priority schools in need of

major academic improvement based on North Carolina accountability measures. The 2009-2010 school year was the third year of the grant.

A continual revision process was a component of the NCIM professional development model. Thus, data collected during the first two years of the project's development and implementation (i.e., from the content specialists reports and Summer Institute evaluations) were used to revise the current practices of the model to better suit the teachers' needs (Confrey, Maloney, & Krupa, 2008). During the first two years of the project, the Summer Institute was offered to three groups of secondary mathematics teachers: mathematics teachers who were implementing the *Core-Plus*; mathematics teachers who were considering implementing *Core-Plus*; and mathematics teachers who were looking for meaningful content and pedagogy to supplement their approaches to teaching traditional high school algebra or geometry.

An overall evaluation report of the project in 2008 indicated that the teachers needed assistance in a few areas. There was concern that the teachers lacked sufficient knowledge of the content to teach the curriculum. Another concern was that they lacked the capacity to execute the curriculum. Overall, their implementation was uneven. The report also highlighted that teachers did not display trust of the curriculum or the confidence to implement the curriculum successfully (Confrey et al., 2008). The third year of the NCIM professional development was designed to address these areas of weakness.

In 2008, teachers participated in a one-week long Summer Institute geared to address the content issues teachers faced. During that week, a group of teachers worked through *Core-Plus* investigations, led by a team of trained national facilitators and experienced North

Carolina teacher leaders. In light of the project’s evaluation findings and in the interest of creating a more meaningful experience for teachers at the NC-STEM partner schools, a second week was added to the 2009 Summer Institute, during which the teachers concentrated on pedagogical issues. As in the previous year, 60 teachers spent the first week experiencing the curriculum from the student perspective as learners. Content issues were addressed and efforts were made to familiarize the teachers with *Core-Plus*. For some teachers, it was their first experience with any reform mathematics curriculum.

The focus of the second week was developing and promoting effective classroom discourse (Herbel-Eisenmann, 2009; Hufferd-Ackles et al., 2004) and formative assessment, both of which are central elements of a reform mathematics curriculum. Discourse conversations during the Summer Institute were guided by the concept of creating a math-talk learning community in their classrooms (Hufferd-Ackles et al., 2004). By “math-talk learning community,” the researchers mean “a classroom community in which the teacher and students use discourse to support the mathematical learning of all participants” (p. 82). The facilitators also guided the teachers in lesson planning, and the teachers were offered numerous opportunities to reflect on their practices and collaborate with other teachers. At the conclusion of the second week of the Summer Institute, teachers planned and taught a *Core-Plus* lesson in groups of three. On the final day of the Summer Institute, the teachers created action plans intended to help them improve their practice.

## **The *Core-Plus* Curriculum**

The curriculum of focus in this study is *Core-Plus Mathematics* (Coxford et al., 1997-2001), one of the NSF high school curriculum projects developed by the Core-Plus Mathematics Project (CPMP). A detailed description of the *Core-Plus* curriculum is included in this section because an understanding of the difference between *Core-Plus* and traditional mathematics curricula is essential to understanding both the need for professional development and the need for this study.

Typically, students take the first three courses of *Core-Plus*, and there is an optional Course 4 designed for those students continuing in college-level mathematics and statistics courses. The first three courses of *Core-Plus* are considered a common core of broadly useful mathematics designed to prepare all students for college, the workforce, and for the demands of daily life. Some students opt to take a traditional Precalculus, AP Calculus, or AP Statistics course instead of the fourth course. The goal of CPMP was to develop and evaluate “instructional materials that will enable high schools to move toward an integrated mathematics sciences curriculum with a significant common core of broadly useful mathematics for all students” (Core-Plus Mathematics Project, 1994, p. xi). During each year of the *Core-Plus* curriculum, mathematics is developed along four interwoven strands: algebra and functions, geometry and trigonometry, statistics and probability, and discrete mathematics. Each year the strands are connected across units by fundamental themes, common topics referred to as mathematical habits of mind. These include visual thinking, recursive thinking, searching for and describing patterns, making and checking conjectures, reasoning with multiple representations, inventing mathematics, and providing convincing

arguments (NRC, 1989; Hirsch et al., 1995; Schoen et al., 1998; Schoen, Cebulla, & Winsor, 2001; Schoen, Fey, Hirsch, & Coxford, 1999; Schoen & Pritchett, 1998). *Core-Plus* emphasizes mathematical modeling, with a specific emphasis on data collection, representation, interpretation, prediction, and simulation. The *Core-Plus* curriculum also emphasizes collaborative learning and communication. In a *Core-Plus* classroom, one will find students working in small heterogeneous groupings the majority of the time.

The second edition of the curriculum materials (Hirsch et al., 2008) was released in 2008 and was designed to build upon the strengths of the first edition. Each *Core-Plus* course of the first edition consisted of seven units, and each unit consists of five multi-day lessons focused on “big ideas” (Schoen et al., 1998). Each course in the second edition consists of eight units, which can last between two and six weeks depending on the unit. Each unit is comprised of two to five multi-day lessons, and each lesson includes two to five mathematical investigations. The curriculum developers included in the first course of the second edition “the most important mathematics all ninth-grade students should have the opportunity to learn” (p. xiii).

The four-cycle phases of classroom activities include – *Launch, Explore, Share and Summarize*, and *Apply*. Each *Core-Plus* lesson is introduced through a problem situation called Think About the Situation (TATS), also referred to as the lesson launch, that provides the context for students and allows them to see the “sense-making power of mathematics” (Coxford & Hirsch, 1996, p. 23). The TATS sets the context for the students’ work to follow. Each lesson is framed by questions meant to focus the students’ attention on the lesson’s key ideas. During the TATS, the students discuss the problem situation as a class. The TATS is



also viewed as a built-in opportunity to promote access and equity in mathematics classrooms (Hirsch et al., 2008).

Once the context is set, students in the second phase work collaboratively, in small groups of four or two, exploring more focused questions and problems related to the launching situation. At the end of their exploration, students participate in a whole class discussion during which groups organize their thinking about the big mathematical ideas and share their insights with the entire class. At the end of their exploration, students participate in a whole class discussion during which groups organize their thinking about the big mathematical ideas and share their insights with the entire class. This is the third phase, Share and Summarize. During the final phase, students work individually on assessment tasks in a section called Check Your Understanding <sup>1</sup>(Coxford & Hirsch, 1996; Schoen et al., 1998; Schoen & Hirsch, 2003b, Coxford et al., 2008, p. xiv).

*Core-Plus* has not only reshaped the mathematics presented, but has also restructured how learning occurs and is assessed (Schoen & Hirsch, 2003a). For a more comprehensive description of the development of *Core-Plus*, the specifics of the curriculum and the instructional model see Hirsch & Coxford, 1997; Hirsch et al., 1995; and Schoen, Bean & Ziebarth, 1996.

### **Purpose and Significance of the Study**

Students in high schools across the United States do not learn the mathematical skills they need in order to be successful in college or in the workplace. Even with changes in curricula and increased accountability measures, many of these students still lack an adequate

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<sup>1</sup> This section is called On Your Own in the first edition of the curriculum materials.

opportunity to learn fundamental math ideas, some from lack of proficiency or interest, and others from weak instructional preparation (Schoen & Hirsch, 2002). Reform-oriented curricula show potential in addressing these issues because of their focus on problem solving in real-world contexts. Given that teachers determine the implemented curriculum and heavily influence the mathematics the students are exposed to, there is a need for a more detailed and qualitative understanding of how teachers integrate their own knowledge, experience and expectations with the use of a new curricular approach and related pedagogical practice. Because *Core-Plus* is an innovative curriculum, districts should expect to have professional development to help teachers with implementation. We need to learn more about what types of professional development models help teachers most. Learning how teachers respond to professional development designed to help them better implement the curriculum is important and timely.

The objective of this study was to conduct case studies in order to investigate practices in teachers' classrooms the semester following their participation in the 2009 NCIM Summer Institute. This study focused on how these teachers implemented the ideas from the Summer Institute. It describes what implementation at the classroom level looks like and seeks to provide insight into factors that influence implementation of *Core-Plus*. Few studies to date have examined the support systems or professional development of teachers implementing these new curricula (Ball, Thames, & Phelps, 2008). This study is significant in that it explored a professional development experience designed to meet the needs of a specific group of teachers based on both research and project evaluation data from previous

years and sheds light on factors that should be considered when designing professional development experiences of this type.

The results of this study will contribute to the research literature in several ways. Because of the heightened concern in improving the mathematical experiences and increasing the mathematical knowledge of all students, exploring the support teachers need to facilitate successful and appropriate implementation of these new mathematics curricula is timely and urgent. Further, this study is situated in the following setting. The schools within which these teachers work are mostly located in rural, high-poverty (characterized by the number of students eligible for free or reduced lunch) school districts. Students of this demographic have been traditionally left out of studies of the curricular effectiveness of *Core-Plus*. This study, while examining in-depth the experiences of two teachers, permits one to consider possible explanations for why implementation of *Core-Plus* is a challenge for teachers and what happens between the teachers' receiving professional development and expectations in student outcomes.

The literature on *Core-Plus* has primarily focused on comparing achievement results of students of the *Core-Plus* and traditional mathematics curricula and recently upon issues concerning measuring level of implementation. Recent studies have suggested critical relationships among teachers' perspectives and experience, their views of reform, their professional development experiences with the curriculum and reform-related pedagogies, student demographic variables, and student outcomes. It is important to recognize that many researchers believe that we can slowly learn what works over time as we amass high quality studies that tell us what works, for whom, and under what conditions.

## **Organization of the Dissertation**

The dissertation is organized into five chapters. Chapter One has introduced the problem of the study and provided an overview of the study. Chapter Two will provide a review of the recent literature on the *Core-Plus* curriculum and its effectiveness, the importance of documenting implementation fidelity, issues related to teachers' transitions from traditional to reform curricula, professional development for teachers, and classroom discourse. The relevant literature is presented to highlight the benefit of conducting the study. Chapter Three presents the research methodology that will be used in the study. In it, the study's approach, research design, and methods are all described. In Chapter Four, answers to the research questions are presented. Finally, Chapter Five discusses the findings of the study in light of the research questions, presents the study's limitations, implications, and areas of research for future exploration.

## **CHAPTER TWO**

### **LITERATURE REVIEW**

This chapter reviews the literature in education relevant to this study. It begins with a discussion of the studies that have examined the effectiveness of *Core-Plus* and compared it to traditional curricula. A discussion of implementation fidelity is included next, followed by a review of relevant literature related to the design of professional development. The chapter concludes with relevant literature on classroom discourse, which is a central element in teaching reform mathematics and a target of the NCIM professional development.

#### **Research on *Core-Plus***

Researchers and school officials alike are interested in examining the effectiveness of *Core-Plus*, but evaluating curricular effectiveness is a complex task. The National Research Council (NRC) (2004) commissioned and charged a panel to review the literature on the effectiveness of curricular programs. Their conclusion was that it was hard to determine the effectiveness of curricula because of “the restricted number of studies for any particular curriculum, limitations in the array of methods used, and the uneven quality of the studies” (p.3). The results of the panel’s work, *On Evaluating Curricular Effectiveness*, provided several recommendations – one of which was the need to consider teachers’ implementation of the curricular materials.

It is important not only to try to determine the effectiveness of curricular programs, but also the conditions under which the curricula are effective. The report suggested that future evaluations of curricular materials use a framework that examines the following components: the program materials and design principles; quality, extent, and means of

curricular implementation; and quality, breadth, and type of distribution of outcomes of student learning over time. Designing and conducting rigorous studies of effectiveness is critical for learning the effectiveness of the curricula.

In most of the *Core-Plus* studies, researchers have made comparisons between the performance of students using the *Core-Plus* curriculum and students using traditional single-subject curricula on various outcomes. These studies have considered students' performance on the Scholastic Aptitude Test (SAT) and the American College Test (ACT) (Schoen & Hirsch, 2003a) and university mathematics placement tests (Schoen et al., 2001; Schoen & Hirsch, 2003b; Lewis, Lazarovici, & Smith, 2001), for example. Several of the studies used data collected during the 1994-1995 national field-testing of the curriculum materials.

Making conclusive claims about student achievement is complicated because results of these studies are varied. Comparing and assessing student learning from different curricula are complex tasks without carefully chosen data collection and analysis procedures (Huntley, Rasmussen, Villarubi, Sangtong, & Fey, 2000). The conflicting philosophies between *Core-Plus* and traditional curricula, and the mathematics students have an opportunity to learn as a result, make this task especially challenging. In an ideal world, the knowledge of students with comparable levels of aptitude would be assessed prior to random assignment to either *Core-Plus* or a traditional curriculum, and their knowledge would be assessed and compared after exposure to the different curricula. This situation, however, is not easy to construct in real schools for various reasons, including time and resources constraints and equity concerns (Huntley et al., 2000; NRC, 2004). At any rate, researchers have attempted to examine the

effectiveness of the curriculum, and the results can be grouped into four areas: student achievement, transition to college, student perceptions, and teacher experiences.

Field-test findings showed strong achievement results of *Core-Plus* students especially in the areas of understanding, reasoning, and problem solving, and tasks involving statistics and probability – all concepts emphasized throughout the curriculum (Schoen et al., 1998; Schoen & Hirsch, 2003a, 2003b; Schoen & Pritchett, 1998). To examine differences in student achievement, Schoen et al. (1998) compared the mean scores of students on the Ability To Do Quantitative Thinking (ATDQT or ITED-Q), a subtest of the Iowa Tests of Educational Development (ITED), at *Core-Plus* field-test schools and matched comparison schools. In that comparison, *Core-Plus* students in Course 1 had a significantly higher mean score on the ITED-Q than comparison students, who had a slightly higher pre-test mean score. A similar three-year trend was found when comparing ITED-Q pre- and post-test means of *Core-Plus* students and the comparison group (Schoen & Hirsch, 2003b).

The data revealed that *Core-Plus* students show deeper conceptual understanding, greater ability to interpret mathematical representations and calculations, and stronger problem-solving skills in meaningful contexts than comparison students. *Core-Plus* students' higher scores on the ITED-Q Interpreting Information and Solving Problems subtests indicate this (Schoen & Hirsch, 2003b). On the other hand, these data showed *Core-Plus* students were not as strong as their comparison counterparts in “out-of-context, paper-and-pencil symbolic manipulation” (Schoen & Hirsch, 2003a, p. 341). Central to the algebra strand of *Core-Plus* is an emphasis on using “modeling of quantitative relationships in contextual problems” (Schoen & Hirsch, 2003b, p. 326) to promote the development of

algebraic ideas, so it seems reasonable that *Core-Plus* students would perform well on tasks of that kind. Likewise, comparison students might be expected to perform well on tasks of symbolic manipulation without context. Comparisons between *Core-Plus* and comparison students' mean scores showed that Course 1 students significantly outperformed all traditional matched comparison groups on contextual algebra problems, but were outperformed in almost every comparison involving procedural algebra skills (Schoen & Hirsch, 2003b). Results from a matched comparison of *Core-Plus* Course 2 students to traditional students showed at the end of Course 2, a statistically significant difference in scores was only found in comparison to the Accelerated Advanced Algebra students. Course 2 students had higher mean scores on contextual and procedural tasks than comparison matched groups, but the differences were not statistically significant (Schoen & Hirsch, 2003a).

Huntley and her colleagues (2000) found that students whose algebra instruction emphasized the use of functions and graphing technology to solve “authentic quantitative” problems were more skilled at solving those types of problems than students who were instructed in environments where that type of instruction was not emphasized (p. 354). The researchers also found that students who spent more time practicing symbolic manipulation tasks were more skilled at problems of that type than students who had spent less time practicing, which might be expected. In particular, their results showed *Core-Plus* students outperforming traditional curricula students on formulation and interpretation questions, in setting up models and solving algebraic problems presented in realistic and meaningful contexts, problems including moving between symbolic, tabular, and graphic representations,



as well as tasks both set in context and allowing the use of calculators. Although *Core-Plus* students were less proficient than were the comparison students in algebraic manipulation, they possessed an ability to solve the same problems in a variety of ways, many of which were calculator-based strategies. Traditional students outperformed the *Core-Plus* students on formal symbol-manipulation tasks without context and calculator use, except for one site in which *Core-Plus* students outperformed the traditional students on this measure. A possible explanation for this conflicting result will be presented later.

A few studies have examined *Core-Plus* students' transition to college (Hill & Parker, 2005; Lewis et al., 2001; Milgram, 2002; Schoen & Hirsch, 2003b), and the results have been mixed, and some study results (Hill & Parker, 2005; Milgram, 2002) are questionable. Using data from field-test schools, Schoen et al.'s (2003a) results showed that the SAT Mathematics mean of students who had completed through Course 3 with *Core-Plus* did not differ significantly from students who had completed the traditional sequence of Algebra, Geometry, and Advanced Algebra. They also showed that the SAT Mathematics mean of students who had completed Course 1 through Course 4 was significantly higher than students who had completed the traditional sequence through Precalculus. In Milgram's (2002) unpublished study in which students reported their own SAT scores, he found the mean SAT Mathematics score of students attending a school using *Core-Plus* was 59 points lower than students attending a school using a traditional curriculum.

The choice of methodology of the studies previously mentioned involving *Core-Plus* is a likely explanation for any inconsistencies in the studies. Consequently, results of the Schoen and Hirsch (2003b) and Milgram (2002) studies should be interpreted cautiously.

Milgram's study sample was self-selecting, which some researchers have criticized, arguing that the 67 *Core-Plus* students who responded to the survey were not representative of the entire school population and whose experiences could be atypical (Hill & Parker, 2005).

Milgram countered this criticism and argued that the same process was used for the comparison group. The argument that there were no selection effects is not convincing, and fails to rule out the possibility that primarily those with negative experiences with *Core-Plus* were over-represented.

Some researchers have also explored how *Core-Plus* students fare on college university placement tests. The results generally show that students who completed traditional mathematics courses in high school scored higher than their *Core-Plus* counterparts did on problems requiring symbolic-manipulation skills (Schoen, Cebulla, et al., 2001; Schoen & Hirsch, 2003b). In two studies though, *Core-Plus* students have been found to score higher on Calculus Readiness concepts (Schoen, Cebulla, et al., 2001; Schoen & Hirsch, 2003b). In contrast, Hill & Parker (2005) found in their study that *Core-Plus* students were enrolled in higher-tier university courses in decreasing numbers and in remedial courses in increasing numbers. Also according to their findings, *Core-Plus* students reported having earned lower grades than comparison students while, on average, enrolled in less advanced courses than the comparison students. In summary though, these various findings are also not conclusive for discerning how *Core-Plus* students will perform on college entrance exams because neither study provided information on the degree of implementation of the compared curricula. Moreover, two of the studies were conducted with schools whose student population was more than 80% white, with Asian students as the largest minority. Thus,

caution should be expressed when attempting to generalize the findings from some of these studies to more diverse populations.

Some studies have attempted to examine outcomes other than test scores or grades. Lewis et al. (2001), in their work, declared that students notice the differences in design and features of reform curricula such as *Core-Plus*. Students specifically have reported differences were between situational, contextual problems versus symbolic, decontextualized problems; focus on conceptual understanding versus symbolic manipulation; collaborative learning experiences in small groups versus individual study; and the central versus tangential role of the graphing calculator. That students notice these differences can be viewed as indication that the curriculum authors have been successful in “reorienting how students see, experience, and learn mathematics” (p. 26).

Studies exploring *Core-Plus* students’ perceptions of the usefulness of the curriculum have also reported mixed findings. Some have shown *Core-Plus* students more positive about aspects of the curriculum and their classroom experiences than comparison students of traditional curricula within their same schools while *Core-Plus* students in other studies have not viewed the differences as favorably. Milgram (2002), for example, found a sizeable difference in the perceptions of students about the usefulness of their high school mathematics curriculum with respect to their college mathematics courses. The *Core-Plus* students, only two of which attempted Calculus as their first university mathematics course, reported lower responses than did the non-*Core-Plus* students when asked how much their high school mathematics curriculum helped them with their university mathematics courses. Again, not all researchers considered implementation of the curriculum; therefore,

concluding that the students' reactions are to the actual curriculum instead of to its subpar implementation would be in error. In addition, one has to weigh the tendency for college placement tests and introductory courses to be heavily dependent on symbolic manipulation which may imply that the different results reflect a misfit between the two levels of curriculum.

### **Implementation Fidelity**

A primary explanation for the inconsistencies in results on the effectiveness of the curriculum is the variation in implementation of the curriculum. In short, a study of the implementation fidelity of a set of curricular materials evaluates whether the use of the curriculum is as the developer intended (Fullan, 2001). Without some measure of implementation fidelity, determining whether negative findings are attributable to an ineffective program or an improperly implemented program is challenging (O'Donnell, 2008).

Considering implementation fidelity in the research on effectiveness of the curriculum is important, so some researchers (Tarr et al., 2010) have confronted the issue of how to measure implementation. Of course, the goal is to improve the mathematics achievement of students by increasing the content they learn, but a full understanding of how the learning occurs cannot occur without taking a careful look at what goes on in the classroom. According to the NRC report (2004), a curricular program's effectiveness depends on how it is enacted, which depends largely upon the school system's capacity to support and sustain the adopted program.

Many research studies have acknowledged that variations in implementation exist or that their studies' conclusions are presented amid a failure to consider implementation fidelity (Huntley et al., 2000; Star, Smith, & Jansen, 2008; Tarr et al., 2008). Research has also indicated that teacher decisions about what to teach affect the content students are provided the opportunity to learn (McNaught, Tarr, & Grouws, 2008). For many, the assumption has been that teachers actually use the textbooks as the authors intended (Porter, 2002; Reys et al., 2003). The reality is that teachers even within the same school may vary in their implementation of the integrated curricula (Reys et al., 2003). Tarr et al. argued that disparities in how teachers will enact the curriculum demand that researchers document fidelity of implementation if they will attempt to establish a link between curriculum type and student achievement.

Senk and Thompson (2008) maintain that any discussion about achievement without considering curricular implementation is incomplete. They offer four reasons why documenting curriculum implementation matters. First, they contend that teachers using the same curriculum materials are not guaranteed to teach the same content – that teachers will choose different lessons to teach. While teachers heavily influence the content students are exposed to, state and/or local curriculum frameworks often influence their decisions about what to cover. Some research has found that teacher decisions about what material to teach are also influenced by past success or failure with similar material. For example, if a teacher has difficulty teaching a section, he or she might be less likely to teach a similar section later. Second, the researchers suggest that teachers using the same curriculum and teaching similar content (i.e., the same lessons), may still assign different problems for students to complete.

As a result, the students in their classrooms would have varying amounts of exposure to problems, depending on what their teacher decided to focus on. The third reason is the variability that exists in instruction even when teachers teach the same lessons. These variations might result because of differences in prerequisite knowledge and/or teacher expectations of student learning. The fourth reason is that teachers' perceptions about what the students need to be prepared for the end of course assessments varies. "[J]ust reporting achievement without some indication of teachers' perception of the extent to which the assessment items reflect the implemented curriculum may lead to biased reporting or inappropriate interpretation of any achievement differences" (Senk & Thompson, 2008, p.12).

Some studies have considered issues of implementation that were certain to influence results obtained. Huntley and colleagues (2000), when conducting their study, made efforts to include only schools whose implementation of the program was in line with the author-recommended conditions (i.e., heterogeneous grouping, covering the intended curriculum units, and using technology and cooperative learning). This is important because of evidence that what is actually focused on in class and what students are provided an opportunity to learn influences what students are able to do as a result of how they were instructed (Smith & Burdell, 2001; Schoen et al., 2001).

Even with the understanding that documentation of implementation is important, some research has shown that some nuances of implementation like supplementing the curriculum materials are still difficult to detect. Tarr et al. (2008) explored levels of implementation of NSF-funded curricula and traditional curricula, student achievement,

enactment of a standards-based learning environment (SBLE), and the relationship between the three. They found non-significant differences between *Core-Plus* and comparison students on both a test of mathematical skills and concepts and mathematical reasoning, problem solving, communication, and skills and procedures, after controlling for students' prior achievement and teacher effects including level of implementation). McNaught et al. (2008), in a study exploring the extent and manner in which teachers use textbooks in their daily instruction demonstrated that the complexity of the situation is greater than it may have been treated in the past. Their analysis revealed that on average 75% of the content appearing in the textbooks is taught to students during a school year. Further, that of the 75% of the content students are taught during a school year, only 60% came directly from the textbook, with 12% of the material coming from other sources. McNaught et al. also found that 27% of the textbook content was taught using supplementary materials. All of this is evidence that teachers mediate the use of the textbook in the classroom, and that is not enough simply to examine student outcome measures solely based on the type of curriculum students are enrolled in.

A study's findings are limited when implementation fidelity of a program according to its philosophy or program theory is undocumented. Variations in implementation fidelity may explain some contradictory results. Huntley et al. (2000) found at a site for their study that teachers divulged during interviews that the *Core-Plus* curriculum had been supplemented with materials giving students more practice to strengthen traditional algebraic skills. In this study, *Core-Plus* students outperformed the control group on algebraic symbolic manipulation tasks, while unable to offer any definitive explanation; they intimated

that this extra practice supplementation might have contributed to the positive results favoring *Core-Plus* students on algebraic tasks. Results have suggested that given the variations in teachers' use of the same curricular materials, one could argue that children enrolled in the same course could be learning completely different mathematics (Lloyd, et al., 2009). A closer look at the teachers' experiences sheds light on how implementation between individual teachers can vary so much.

### **The Role and Experiences of *Core-Plus* Teachers**

Research on practicing teachers is an emerging field of research (Sowder, 2007). Across studies though, there is much agreement that teachers play a significant role in the learning experiences of students. Lloyd et al. (2009) describe teachers as the “central players in the process of transforming curriculum ideals, captured in the form of mathematical tasks, lesson plans and pedagogical recommendations, into real classroom events” (p. 3). Likewise, according to Garet, Porter, Desimone, Birman, & Yoon (2001), teachers are at center of reform so the success of education reform initiatives centers around their qualifications and effectiveness. That is, if reform efforts are to be effective and sustainable, teachers must develop the capacity to implement them.

The literature has revealed that *Core-Plus* requires adjustments from the students' perspective, but implementing *Core-Plus* also represents a challenging transition for many teachers (Ziebarth, 2001). Teachers have expressed discomfort and difficulty transitioning from a traditional classroom experience to finding the balance between teacher direction and student independence called for by *Core-Plus*. They sometimes find it difficult to accept that their students are able to make important connections without a direct explanation from their



teacher (Wilson & Lloyd, 2000). This transition can be tough for some teachers because they are unable to separate their ideas about the mathematics from how to teach the content.

Learning to find the balance will take teachers time during which they will need to increase their familiarity with the curriculum and become more comfortable with what student behavior resembles in a student-centered environment (Lloyd, 1998).

A small body of research has examined the instructional practices and mathematical conceptions of teachers implementing *Core-Plus* (Arbaugh et al., 2006; Lloyd, 1998; Wilson & Lloyd, 2000). In line with research cited, Arbaugh et al. (2006) found teachers' implementation of the curriculum to span a wide continuum. Variations in implementation arise because of teacher decisions about how to enact the curriculum. Teacher beliefs, experiences, and understanding of mathematics have all been found to influence pedagogical decisions (Lloyd, 1999; Lloyd et al., 2009). In Arbaugh et al.'s (2006) study of twenty-six teachers who taught at least one mathematics course in which *Core-Plus* was used, teachers' lessons were grouped into three groups, low-lesson quality (LLQ), medium-lesson quality (MLQ), and high-lesson quality (HLQ), using classroom observations and a lesson protocol for examining lesson implementation. In short, they found that teachers' beliefs mediated the relationship between the textbook and their instructional practices. How the teachers implemented the curriculum was related to their beliefs about their students' ability to do the mathematics and how appropriate they felt the textbooks were for all students. In the LLQ lessons, teachers were less likely to press students for justifications, and instead there was a greater focus on correct answers. Teachers were likely to adapt activities in ways that would reduce the cognitive demand. They used technology in their lessons, but often only to record

or present information or perform computations rather than analyzing or communicating information. On the contrary, in the HLQ lessons, teachers used the *Core-Plus* curriculum materials and lowered the cognitive demand of activities less often. Their students used their own strategies and were encouraged to reflect on their strategies.

Some research findings raise concern about teachers of students with lower mathematical achievement. These concerns are significant because *Core-Plus* was designed with the interest in making mathematics more accessible to all students (Core-Plus Mathematics Project, 1994, p. xi; Schoen et al., 2001). In a study examining teacher variables and their relationship to student achievement, Schoen et al. (2001) found that teachers with students scoring in the first quartile on the Ability to Do Quantitative Thinking (ITED-Q), a subtest of the Iowa Test of Educational Development, perceived themselves as better informed about the *Core-Plus* curriculum and its use than teachers of students scoring in the fourth quartile. First quartile teachers also had attended a *Core-Plus* summer workshop at a higher rate and expressed greater comfort with the changes in the classroom experience like the role of managing small group work and the non-traditional ways of assessing students than fourth quartile teachers. Fourth quartile teachers expressed that *Core-Plus* required too many changes at once. In Arbaugh et al.'s (2006) study, they found that teachers of LLQ lessons had low expectations for their students' ability to learn the mathematics. They were concerned about their students' lack of basic or prerequisite skills, and thought they needed more practice. On the other hand, teachers of the HLQ lessons were also concerned about what skills their students might need for college entrance exams, but possessed a positive attitude towards the textbook and believed it was appropriate for all students. Further they

believed that any deficiencies their students had could be addressed using *Core-Plus*, while the belief among some teachers of LLQ lessons was that success with *Core-Plus* depended on the “type” of student. These results confirm the need to design and conduct more studies investigating the teaching behaviors and beliefs and curriculum implementation strategies most associated with student learning. The results also highlight the need to provide teachers with support when implementing *Core-Plus*. The results also suggest that teachers of students struggling academically in mathematics may need even more support.

Some of studies of the teachers’ experiences were conducted with either a small number of participants or a small number of observations or interviews of the participants involved. Given the consistency with the other literature highlighting the fact that teachers varied in their implementation of the curriculum, it is unlikely that the differences observed were artificial. It has been recommended that future studies should include more observations with a larger number of teachers (Schoen et al., 2001). Herbel-Eisenmann, Lubienski, & Id-Deen (2006) also suggested that studies of teacher instruction, especially those examining changes in instructional practices, should examine more than one section of a teacher’s day because differences in things like student expectations could vary between classes and could alter the way the teacher presents the material.

Switching to a reform-oriented curriculum requires teachers to change their approaches to the teaching of mathematics. In fact, the success of curricula like *Core-Plus* depends on such changes in teachers’ beliefs. As Ernest (1988) argues, “Teaching reforms cannot take place unless teachers’ deeply held beliefs about mathematics and its teaching and learning change” (p. 1). According to Lloyd and Wilson (1998), “[I]f we are to support

teachers in making long-term instructional changes, it is crucial to continue to investigate the process through which the current reform agenda is interpreted and personalized by teachers involved in the implementation of innovative curricula” (p. 272). Although some administrators and school officials view the textbook as the most important catalyst for changing what occurs in mathematics classrooms, it is unlikely that the adoption of the curriculum alone will transform the instructional practices of teachers (Arbaugh et al., 2006; Wilson & Lloyd, 2000). What is most significant to learn from these studies is how essential professional development is for a successful implementation of *Core-Plus* and the need for this professional development to meet the needs of a diverse group of teachers even within one school. In addition, because implementation of the curriculum is so important to drawing conclusions about student outcomes, support mechanisms should be provided to help teachers adjust to teaching the curriculum.

### **Professional Development**

The body of research on professional development, teacher learning, and teacher change continues to grow. During the past two decades, the concept of professional development has evolved. The traditional one-shot workshop model has been deemed ineffective, and there has been a shift towards the creation of learning communities and ongoing professional development for teachers (Darling-Hammond & Richardson, 2009). The latter is viewed as a more powerful and meaningful way to conduct professional development. Few people would debate the need for ongoing professional development (Loucks-Horsley, Hewson, Love, & Stiles, 1998). Research has emphasized the connection between reform initiatives and professional development – that improvements in education

rarely take place without professional development (Guskey, 2000). Since the publication of the *Standards* (NCTM, 1989) and *Professional Standards for Teaching Mathematics* (NCTM, 1991) documents, the demand for professional development has increased. Education reform initiatives call for a more balanced approach – a shift to placing more emphasis on students’ understanding. This shift means that teachers “must learn more about the subjects they teach, and how students learn these subjects” (Garet et al., 2001, p. 916). Also within these reform initiatives, teachers are challenged to both know their content area in-depth and be able to teach the subject material to a diverse set of learners (Loucks-Horsley, et al., 1998). New curricula, textbooks, mandates, nor tests can be considered sufficient on their own for producing greater student understanding (Darling-Hammond, 1998). Darling-Hammond and McLaughlin (1995) argue that in order for teachers to gain a deep understanding, they must “learn about, see, and experience” the types of learning situations they are being expected to facilitate (p. 599). Researchers agree that one of the most important elements of professional development for teachers new to *Core-Plus* includes first-hand experiences as students, working through investigations to enable them to see the importance of small group work and of the textbook structure (Darling-Hammond & McLaughlin, 1995; Lloyd, 1999; Lloyd, 2000; Schoen & Hirsch, 2003b; Ziebarth, 2001). According to Lloyd (2000), “Engagement with curriculum *as learners* invites teachers to think about challenging mathematics and the nature of mathematical activity, reflect on the process of learning mathematics to develop empathy for future students , and contemplate teaching mathematics to create new personal visions of classroom practice” (p. 154).

Some studies of teacher learning and reform curricula have shown that teachers are often able to implement some of the aspects of reform-oriented mathematics instruction.

Kazemi and Stipek (2001) explain:

They give multi-level problems that are connected to real-world experiences, provide manipulatives for students to use, and offer opportunities for children to work collaboratively in pairs or small groups. They ask students to present their strategies and solutions to the class, and they try to make mathematics activities more interesting. (p. 60)

One could argue that these elements are easy to implement given the nature of the curricula used; however, a move beyond this superficial implementation is necessary to see real improvements in students' understanding and performance. The superficial changes teachers easily make in their teaching practice when adapting to a reform-oriented curricula are necessary, but far from sufficient for exhibiting the instruction called for by the *Standards* documents. The research presented on the implementation of *Core-Plus* has maintained that teachers will need professional development in order for students to succeed because of the connection between student learning and the experiences their teachers provide (Murray, Ma, & Mazur, 2009).

Various definitions of professional development have been put forth. Regardless of the definition though, the term *professional development* encompasses the idea of increasing the capacity of teachers. Elmore (2002) defines professional development as “a set of knowledge- and skill-building activities that raise the capacity of teachers and administrators to respond to external demands and to engage in the improvement of practice and

performance” (p. 13). Professional development, according to Loucks-Horlsey et al., (1998) refers to “the opportunities offered to educators to develop new knowledge, skills, approaches, and dispositions to improve their effectiveness in their classrooms and organizations” (p. xiv). They distinguish between in-service education, staff development, and training because professional “signifies a commitment to continuous learning” (p. xiv). Professional development in this era of reform, according to Darling-Hammond and McLaughlin (1995) means “providing occasions for teachers to reflect critically on their practice and to fashion new knowledge and beliefs about content, pedagogy, and learners” (p. 597).

Much of the recent literature on professional development has highlighted a need to rethink the structure of professional development experiences for teachers. Professional development opportunities and practices, according to Speck and Knipe (2005), should challenge teachers, support their growth and provide opportunities for teachers to reflect on their practices. Loucks-Hoursley et al. (1998) speak of a paradigm shift in professional development, one in which there is less emphasis on transmission of knowledge and more on experiential learning. What is known and agreed upon is that many teachers were trained to teach in a style emphasizing memorizing facts, with less of an emphasis on a deep understanding of the subject matter (Darling-Hammond & McLaughlin, 1995). In addition, professional development that helps improve the quality of educational experiences for children should increase the knowledge and skill of educators (Elmore, 2002; Speck & Knipe, 2005).

Past professional development efforts have been criticized for several reasons. For one, professional development efforts that occur out of context are considered less than ideal. Professional development efforts that are not relevant to teachers' experiences and are short-lived are also criticized. Efforts in which teachers are only passive participants, that contain fragmented activities, and do not allow opportunities for collaboration are not considered effective professional development techniques. Elmore contends that instead, effective professional development should be connected to real questions and problems of teachers in real classrooms and should be designed to develop capacity of teachers to work collectively on problems of practice within own schools and with other practitioners. Moreover, it should be designed with challenges and support for teachers to grow, change, and reflect on their practices (Elmore, 2002; Speck & Knipe, 2005).

As mentioned earlier, teaching *Core-Plus* requires a transition for most teachers. Because teachers were not taught or trained to teach in the ways called for by the *Standards* documents (Ball, 1998; Cohen & Ball, 1990; Fullan, 1991), some teachers are plausibly unclear about how to teach such a different curriculum. Also included in the professional development literature, is the idea that not only does practice need to change, but so does teachers' thinking (Elmore, 2002). Given that teachers might find it easy to implement *Core-Plus* on the surface, professional development for *Core-Plus* teachers will need to focus on getting teachers accustomed to a new way of teaching mathematics. Traditional professional development has tended to give little consideration to participating teachers' experiences and perceived needs. As such, some teachers view professional development as having no connection to practice and therefore participate passively.



As Elmore (2002) asserts:

To the degree that people are being asked to do things they don't know how to do and, at the same time, are not being asked to engage their own idea, values and energies in the learning process, professional development shifts from building capacity to demanding compliance" (p. 12).

Elmore also maintains that professional development designed for the outcome of significant changes in practice should "focus explicitly on the domains of knowledge, engage teachers in analysis of their own practice, and provide opportunities for teachers to observe experts and to be observed by and to receive feedback from experts" (p. 16). Ball and Cohen (1990) posit that to be sure teachers are having authentic learning experiences that are connected to their actual classroom experiences, professional development activities and experiences should be practice-based and have teachers' own practice, learning, and students at their source. In line with Elmore (2002), other researchers also argue that professional development should include opportunities for teachers to reflect on their practice within the context of their daily classroom experiences (Hawley & Valli, 1999; Putnam & Borko, 2000; Wilson & Berne, 1999).

Darling-Hammond (1998) argues that achieving high levels of student understanding necessitates supporting teachers' continuous learning. Moreover, before teachers can help students increase their level of understanding, they must possess a deep and flexible understanding of their subject matter (Darling-Hammond, 1998). She further argues that teachers need to be able to see how ideas connect across fields and that this type of understanding is the foundation for the pedagogical content knowledge of which Shulman

(1987) speaks. Darling-Hammond puts forth a number of things teachers need to be able to do to help students acquire a deeper understanding of the subject matter, one of which is an ability to “analyze and reflect on their practice, assess the effects of their teaching, and to refine and improve their instruction” (p. 8). Darling-Hammond and McLaughlin (1995) posit that in order to help teachers teach according to education reform initiatives, effective professional development in which teachers assume both the role of teacher and learner are required. Ball and Cohen (1999) go further and assert that the professional development should actually take place in a reform-type environment. All of this means that passive participation in professional development for teaching a reform-oriented curriculum such as *Core-Plus* is not likely to result in changed practice. Professional development activities, during which teachers are lectured at by an expert or panel of expert teachers, are no longer viewed as effective. It seems the consensus that simply telling teachers what to do differently in their classrooms will not work when transitioning to teaching with *Core-Plus*.

In order for teachers to develop a teaching practice so different from the learning experiences they have experienced themselves (both as teacher and student), opportunities for them to learn what the new practice entails must be presented that are more than simply talking about new pedagogical techniques (Darling-Hammond, 1998; Darling-Hammond & McLaughlin, 1995). She puts it simply: “Teachers learn best by studying, doing, and reflecting; by collaborating with other teachers; by looking closely at students and their work; and by sharing what they see” (p. 8). What is important to note is that this type of learning cannot occur disassociated from practice. Having this set of experiences is particularly helpful when adapting to teaching *Core-Plus*.

Teachers are not the only school officials who would benefit from professional development activities within this era of reform. Darling-Hammond and McLaughlin (1995) argue that the same need for teachers (i.e., to engage in collaborative inquiry and learning) also exists for principals and other school staff. Darling-Hammond and McLaughlin contend that the environments in which some teachers work send many signals about how schools are supposed to operate and about which behaviors and skills are rewarded. Many of these signals are often in conflict with each other. Furthermore, they argue that the system of evaluation teachers should be called into question because some evaluation processes are based on the assumption that teaching is simply implementing routines that can be easily observed and checked off during a brief inspection. The notion of evaluation is an important one since many teachers' instruction is likely to be influenced by their administrator's impending evaluations. Darling-Hammond and McLaughlin argue that it is no longer sufficient to "focus on teachers' adherence to prescribed routines, and that evaluation should be viewed as an ongoing aspect of classroom life. They argue that teachers must feel safe to try new practices and make mistakes.

Successful implementation of mathematics education reform will not occur without changes in teachers' instructional practices. These changes include a shift in what it means to teach mathematics (Ball, 1998; Ball & Cohen, 1999; Darling-Hammond & McLaughlin, 1995; Hufferd-Ackles et al., 2004; Loucks-Horsley et al., 1998). These changes in practice are hard. Researchers have investigated teachers' transitions from traditional instructional practices to those more aligned with reform mathematics curricula and have found that increased subject matter knowledge and pedagogical content knowledge were needed for this

transition (Cohen, 1990; Fennema & Nelson, 1997; Wood, Cobb, & Yackel, 1991). As previously stated, there is still much to learn about what types of professional development models help teachers most.

While research has shown that teachers implementing *Core-Plus* will need professional development, it is crucial that these professional development experiences embody the characteristics of what research considers effective professional development. While considering curricular materials adoption, districts or schools considering adopting *Core-Plus* are best advised to think about the support and professional development mechanism their teachers will need to aid in the curriculum's implementation.

### **Building a Mathematics Discourse Community**

Research has indicated that teachers need help with establishing and facilitating the discourse community referred to in the NCTM *Standards*. NCTM's *Professional Standards for Teaching Mathematics* (1991) placed emphasis on establishing a mathematics discourse community. The role of discourse in mathematics classrooms is receiving increased attention because of the interest in learning what types of educational experiences lead to increased student learning (Cobb, Boufi, McClain, & Whitenack, 1997; Knuth & Peressinin, 2001). Contemporary educational reform calls for discussion about the curricular content that is student-led and student-centered (Knuth & Peressinin, 2001; Nathan & Knuth, 2003). Six standards for teaching mathematics were identified in the *Teaching Standards*, one of which highlights the role of the teacher in discourse. According to the document,

Discourse refers to the ways of representing, thinking, talking, agreeing, and disagreeing that teachers and students use to engage....The discourse embeds

fundamental values about knowledge and authority. Its nature is reflected in what makes an answer right and what counts as legitimate mathematical activity, argument, and thinking. Teachers, through the ways they orchestrate discourse, convey messages about whose knowledge and ways of thinking and knowing are valued, who is considered able to contribute, and who has status in the group (NCTM, 1991, p. 20).

The standard depicts the following elements of a teacher's role in discourse:

(a) posing questions and tasks that elicit; (b) engaging and challenging each student's thinking; (c) listening carefully to each student's ideas; (d) asking students to clarify and justify their ideas orally and in writing; (e) deciding what to pursue in depth from among the ideas that students bring up during a discussion; (f) deciding when and how to attach mathematical notation and language to students' ideas; (g) deciding when to provide information, when to clarify an issue, when to model, when to lead, and when to let a student struggle with a difficulty; and (h) monitoring students' participation in discussions and deciding when and how to encourage each student to participate (p. 35).

NCTM's (2000) *Standards* also emphasized the importance of students learning in a mathematics community with the idea that students who learn mathematics in this way will be able to communicate their mathematical ideas and strengthen their mathematical understanding (Hufferd-Ackles et al., 2004).

The typical sequence of events in many traditional mathematics classrooms is the Initiate-Respond-Evaluate sequence described by Mehan (1979) and Sinclair and Coulthard

(1975). In this sequence, the teacher “initiates” by choosing the task and asking the students to provide the answer. The student “responds” by giving an answer, and the teacher “evaluates” by giving feedback on the student’s answer before moving on (Herbel-Eisenmann, 2009). Cazden (2001) explains that during this sequence, the teachers’ questions are primarily inauthentic questions to which he or she already knows the answer. The teacher is either testing the students or co-opting them into a lesson that would otherwise be a lecture (Cazden, 2001). NCTM *Standards* stresses the importance of communicating using mathematical language for learning instead of simply following a sequence of procedures (Cazden, 2001; Nathan & Knuth, 2003). The idea is that dialogue results in deeper conceptual understanding of mathematics for all students, and with the ultimate goal of the teachers’ facilitation of student-to-student dialogue (White, 2003).

The growing interest in discourse in mathematics classrooms is not surprising given the different vision of learning of mathematics portrayed in the NCTM *Standards* documents (Nathan & Knuth, 2003; Silver, 2009). In reform-oriented mathematics classrooms as opposed to traditional mathematics classrooms, knowledge is not just transmitted from the teacher to students. Instead, the role of teacher is “diversified to include posing worthwhile and engaging mathematical tasks; managing the classroom intellectual activity, including the discourse; and helping students understand mathematical ideas and monitor their own understanding” (NCTM, 1991, p. vii). In order for classrooms to take on the vision of reform mathematics, communication is essential. Researchers use slightly different language to talk about the building of the mathematics learning community described by the NCTM *Standards*. To illustrate, Hufferd-Ackles et al., (2004) speak of a math-talk learning

community, while Nathan and Knuth (2003) refer to classroom mathematical discourse. Regardless, the interest is in developing a student-centered learning environment in which all students participate and all ideas are valued. Developing a discourse community or math-talk learning community (Hufferd-Ackles et al., 2004) is intrinsic to enacting mathematics reform practices inherent in *Core-Plus*. White (2003) asserts that productive classroom discourse is when teachers “engage all students in discourse by monitoring their participation in discussion and deciding when and how to encourage each student to participate” (p. 37).

Even with this growing awareness in the importance and necessity of fostering a discourse community in mathematics classrooms, results of research consistently suggest that the development of such a discourse community can be an intimidating and overwhelming task for some teachers (Hufferd-Ackles et al., 2004; Kazemi & Stipek, 2001; Silver, 2009). Some teachers, in fact, may find that they have no idea where to even begin the task of creating the type of learning community called for by NCTM (Herbel-Eisenmann, 2009; Hufferd-Ackles et al., 2004; Silver & Smith, 1996). Teachers of both the LLQ and HLQ lessons in Arbaugh et al.’s (2006) study were concerned with their ability to facilitate discourse and manage small groups. Teachers assigned to the HLQ group valued the small-group work called for by the textbook, but realized they needed to make improvements in their ability to manage the groups.

The building of this community is a gradual process. There are several shifts that occur when transforming a teacher-centered learning environment to a mathematics classroom environment more aligned with reform mathematics teaching. Students and the teacher are required to assume new roles in their relationship. Teachers no longer assume the

role of sole authority of knowledge. There is a shift from the teacher as sole questioner to both teacher and students acting as questioners. Students begin to explain more than their procedural steps for solving problems, and they improve in articulating their thinking about mathematics. The students begin to take more responsibility for their learning, and actually monitor and evaluate themselves (Nathan & Knuth, 2003). Research indicates that is a difficult shift for teachers to make. Even in the HLQ lessons in Arbaugh et al.'s (2006) study, the teacher remained the authority in the classroom. Hufferd-Ackles et al. (2004) emphasize the need for systems of teacher professional development aimed at helping teachers facilitate a mathematics discourse community.

They identify the challenges teachers encounter when trying to establish a discourse community within their classrooms and implementing reform practices that research has documented. Teachers may find that students disengage as they are presented with more challenging tasks (Romagnano, 1994; Stein, Grover, & Henningsen, 1996). Teachers may also find it more difficult to manage the direction of their instruction when they open up their classroom for students to contribute their ideas. Teachers may be unsure of how to respond when students make incorrect mathematical claims (Sherin, 2002a; Silver & Smith, 1996). Arbaugh et al. (2006), for example, found that teachers assigned to the LLQ group focused only on correct answers, rarely, if ever, following up on unclear or incorrect responses. They were quick to correct mistakes instead of use them for opportunities for learning. There are also challenges regarding teachers' sense of self-efficacy. Teachers experiencing these reform curricula may find it tough to predict the direction of a lesson and more difficult to



anticipate student responses and prepare for how they might respond (Heaton, 2000; Sherin, 2002b; Smith, 2000).

Teachers may also find that as they work on developing a mathematics discourse community that their conversations have less precision than when they led and were at the center of the discussions, even though student participation increases (Nathan & Knuth, 2003). They also may struggle deciding between valuing all student contributions to the mathematics discussion equally versus indicating those that are particularly valuable in terms of the mathematics expressed, particularly when any student contributions may not move forward the mathematical agenda of the class (Nathan & Knuth, 2003). What is so important to note is that simply creating the space for students to interact with each other more regularly during discussion or promoting more student-to-student interactions is insufficient. There is still a need to support the students' learning of the mathematics during the discourse (Nathan & Knuth, 2003). This requires teachers to "strike a balance" between "the social and analytical demands, that is when students' own social constructions of mathematical ideas are also connected to the ideas and conventions of the mathematical community" (Nathan & Knuth, p. 203). The research suggests that while the establishment of a classroom discourse community is vital to implementing these reform curricula, teachers may struggle with this transition (Hufferd-Ackles et al., 2004). For these reasons, teachers will need support while making this transition.

Another problem is that many teachers trying to enact reform-based practices in their classrooms have not been prepared to do so by their mathematics teacher education and professional development experiences. Moreover, many of the teachers have also not had

experiences actually participating in the type of discourse they are now expected to promote (Nathan & Knuth, 2003). Nathan and Knuth acknowledge two challenges facing teachers attempting to enact reform-based practices: (a) figuring out how to manage stepping in and out of the conversation, and (b) learning what their role as the teacher is in the discourse.

As stated previously, Hufferd-Ackles et al. (2004) refer to a discourse community as a math-talk learning community. By math-talk learning community, the researchers mean “a classroom community in which the teacher and students use discourse to support the mathematical learning of all participants” (p. 82). The primary goal of this community is “to understand and extend one’s own thinking as well as the thinking of others in the classroom” (p. 82). The researchers articulate a framework, *Levels of the Math-Talk Learning Community: Action Trajectories for Teacher and Student*, through which they describe the growth in a math-talk learning community through developmental stages. The framework comprises four components: (a) questioning, (b) explaining mathematical thinking, (c) source of mathematical ideas, and (d) responsibility for learning. The framework depicts four levels through which movement occurs from a traditional mathematics classroom, in which the teacher is the sole questioner and students act as passive listeners (Level 0) to a classroom displaying elements of a reform mathematics classroom, in which students and the teacher are both co-teachers and co-learners. The framework (presented in Appendix A) describes the teacher and student behaviors of each component displayed at each level. Teacher behaviors are italicized (Hufferd-Ackles, 2004).

Some of the research on classroom discourse has been general in nature or applicable to various classroom settings. A connection to the content or the subject of the discourse is

missing. For instance, in an exploration of how a middle school teacher attempted to alter her classroom practice to one more aligned with her view of reform mathematics, after the second year of reflection the teacher reported that she sometimes wondered if the students were “getting the math” (Nathan & Knuth, 2003). While her students were interacting with each other more, she questioned whether they were actually learning the mathematics. The researcher proposed a couple of reasons for her thoughts. For one, students argue that the teacher’s attention was shifted from the specific mathematical talk among students prompted by her shift in focus on social scaffolding. Second, students suggest that the teacher stopped using prompted discourse (initiated and for the most part directed by the teacher) to learn how much the students actually know. Prior to working on aligning her classroom practices with her vision of reform-mathematics instruction, the teacher asked questions with specific expectations in mind. It was more challenging for her to monitor the unprompted discourse. All of this suggests that more research attention should focus on trying to draw a stronger connection between the facilitation of a mathematics discourse community and the mathematics students actually learn.

Gall (1970) in a paper written decades ago to suggest areas for research into teachers’ questioning techniques reported that teachers tend to ask a great number of questions, but that the overwhelming majority of their questions called for direct recall of information from the textbook. She explains that the first study of teacher questioning conducted in 1912 and a study conducted nearly fifty years later found similar results – that the majority of teachers’ questions were recall questions. With the adoption of reform curricula like *Core-Plus*, it is important to pay close attention to implementation so that the exhibition of the behaviors

called for by *Core-Plus* does not become the goal. As Gall writes, “It is important that teachers’ questions should not be viewed as an end in themselves. They are a means to an end – producing desired changes in student behavior” (p. 718). As such, the adoption of *Core-Plus* should not be viewed as an end itself. Instead, the result is increased student understanding and performance, both of which will not be reached with simply a superficial implementation of the curriculum.

### **Summary**

While the NCTM reform documents influence changes in teachers’ practices, a challenge in implementing reform-based practices is the vagueness in what it actually means to teach according the reform principles (Sfard, 2000). “The goals are ill-defined, the effects of discourse on learning are unclear, and the means to promote it are poorly understood” (Nathan & Knuth, 2003, p. 202). The NCTM *Standards* documents provide guidelines for teachers with little explicit instruction and guidance for teacher in reshaping their instruction. The vagueness lends itself to multiple interpretations of the basic tenets or reform in mathematics education. Such ambiguity also supports the need for professional development to aid in the transition. Professional development is the key to helping teachers make the transition to teaching reform mathematics curricula like *Core-Plus*. It is important that the professional development activities designed for that purpose possess the characteristics and features of effective professional development. Worth pointing out is that “any discussion of the challenges to implementing reform must also acknowledge the complex nature of the classroom that encumbers its ability to respond to all influences” (Nathan & Knuth, 2003, p. 202). Therefore, what must also be kept in mind is that the changes in mathematics

instruction within classrooms are expected to occur within the larger context of heightened accountability, high-stakes testing, and community influences, including parents (Nathan & Knuth, 2003).

In the next chapter, the study's design and methods will be presented. Chapter Three details the research strategy, research questions, methods, limitations, and ethical considerations. It also includes a statement of my subjectivities.

## **CHAPTER THREE**

### **METHODS**

The previous chapter provided an overview of the recent literature on the effectiveness of the *Core-Plus* curriculum, teachers' experiences using the curriculum, and the professional development needs of the teachers using the curriculum. This study contributes to our understanding of how mathematics teachers respond to professional development targeted at helping teachers foster improved implementation of an integrated curriculum, deepen their underlying content knowledge, and promote increased and productive classroom discourse. It focuses on how what the teachers learned during the Summer Institute plays out in classroom practice and outlines the challenges they faced in the process of curriculum implementation. The findings can help influence the design of future professional development models intended to promote a change in practice by highlighting concerns that should be taken into consideration in its development.

In this chapter, I provide a description of the participants in the study, the methods employed to answer the research questions, the study's design, the research study procedures, and methods of data collection. A description of the instruments, data analysis, and strategies for addressing reliability and validity and ethical considerations are also presented.

#### **Purpose of the Study and Research Questions**

The purpose of this study was to investigate the effect of a professional development intervention (NCIM) on the instructional practices of the teachers at the NC-STEM partner schools during the fall semester of the 2009-10 academic year. The NCIM Summer Institute was designed to improve teachers' instructional practices while implementing *Core-Plus*

(Confrey et al., 2008). This study focuses on how these teachers implemented the ideas from the Summer Institute and incorporated the assistance provided during the follow-up content specialist visits. It also examines any obstacles the teachers encountered while attempting to implement *Core-Plus* and enact the practices modeled during the Summer Institute.

This study addressed the following research questions:

- 1) What challenges or obstacles, if any, do the teachers encounter while using the *Core-Plus* curriculum materials and attempting to apply the ideas presented during the 2009 NCIM Summer Institute?
- 2) How do teachers attempt to develop a math-talk learning community after participating in the 2009 NCIM Summer Institute?

### **Context and Participants**

Teachers from around the state<sup>2</sup> were invited to participate in the NCIM Summer Institute. Teachers at the NC-STEM partner schools were especially encouraged to participate in the NCIM professional development because for many of them it was their first time teaching *Core-Plus*.

#### **NCIM Summer Institute.**

The North Carolina Integrated Mathematics Project (NCIM)<sup>3</sup> was developed with the understanding that teachers would need support when implementing a new curriculum like *Core-Plus*. During the summer of 2009, the teachers involved in this study participated in the

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<sup>2</sup> Each summer, teachers from all over North Carolina participated in the Institute, but did not receive follow-up support from content specialists the next year.

<sup>3</sup> The NCIM professional development model was developed as part of the NC-STEM Mathematics Science Partnership Grant from the North Carolina Department of Public Instruction (NCDPI), in collaboration with the North Carolina New Schools Project (NCNSP) and North Carolina State University (NCSU) to assist North Carolina teachers with implementing the *Core-Plus* mathematics curriculum.

two-week NCIM Summer Institute. During the first week of the Summer Institute, teachers were given the opportunity to explore the mathematics curriculum from the perspective of the student. This aspect was included because of research (Darling-Hammond & McLaughlin, 1995; Lloyd, 1999; Schoen & Hirsch, 2003; Ziebarth, 2001) showing that teachers using reform curriculum materials need first-hand opportunities working through the investigations as students would. Each day during the first week, trained facilitators and experienced North Carolina teacher leaders led the teachers through lessons in the textbook. There were facilitators for the first three courses, and most Institute participants enrolled in the first course. Teachers registered for a course based on their teaching assignments for the upcoming academic year and their prior experience with the curriculum.

Based on the evaluation data from the 2008 Summer Institute and content specialist reports on visits during the 2008-09 school year, the project directors and research team decided to add an additional week. Another research team member and I were influential in the design of the second week. We led discussions about what should be included based on what we had read in the observation reports, recent literature on professional development and teaching with a reform mathematics curriculum, and from the teachers' responses to the 2008 Summer Institute. We designed the second week of the Summer Institute to focus on aspects of instruction including planning, formative assessment, and promoting discourse in mathematics classrooms (Herbel-Eisenmann, 2009; Hufferd-Ackles et al., 2004; Nathan & Knuth, 2003; Stein, 2007; Sherin, 2002; White, 2003). The facilitators guided the participating teachers in lesson planning and presented them numerous opportunities to reflect on their practices and collaborate with other teachers. At the conclusion of the second



week of the Summer Institute, teachers planned and taught a *Core-Plus* lesson in groups of three. On the final day of the Summer Institute, the teachers created action plans intended to help them improve their practice. Teachers at the NC-STEM partner schools returned to their classrooms the following semester to implement the curriculum with the assistance of content specialists who made at least monthly visits and provided on-site coaching for the teachers.

### **Participants.**

Six secondary grades teachers from three of the NC-STEM partner schools participated in the 2009 NCIM Summer Institute. The redesigned high schools were associated with the North Carolina New Schools Project and were created after the schools from which they were created had been recognized as schools in need of significant academic improvement. The schools joined a collaboration called the North Carolina New Schools Project and adopted a focus on STEM (Science, Technology, Engineering, and Mathematics) education. Of those six teachers who participated in the Summer Institute, five teachers, Trisha<sup>4</sup>, Leslie, India, Mark, and Fawn, at three different NC-STEM partner schools participated in both weeks of the Summer Institute. Those five teachers were asked to participate in this study.

We met with all five teachers during the Summer Institute. During the meeting, I described the research study and asked whether the teachers would participate in the study. All five agreed to participate. We asked the teachers to choose one class to be the subject of the research for this study and to choose two investigations that we could video-record. We also explained that we would schedule interviews with them during our visits and conduct

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<sup>4</sup> All names reported are pseudonyms.

informal observations without the video cameras as well. Only three of the five teachers participated in all aspects of the data collection, Leslie, India, and Trisha. This study, however, focuses only on the experiences of Leslie and India.<sup>5</sup> The goal of the study is to understand how these two teachers implemented the ideas from the Summer Institute and identify any challenges they faced.

### **Securing approval and access to the sites.**

In addition to securing university Institutional Review Board (IRB) approval, permissions were obtained to conduct research at the schools with each teacher's school district. Initial phone calls were made to establish contact with the appropriate officials responsible for making such approval decisions, and copies of the research proposal and consent forms were e-mailed and mailed to them. Follow-up e-mails and phone calls were placed and any procedures for securing additional approval were adhered to before commencing data collection.

Before scheduling any school visits and collecting any data, consent forms were distributed and collected from students, parents, and teachers. The consent forms provided a description of the research study, described what participation entailed, and highlighted the voluntary nature of participation in the study and that participation could be withdrawn at any

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<sup>5</sup> Because the case study was focused on exploring how teachers adapted their practices to enact *Core-Plus* and develop a discourse community, it was important to garner episodes of them teaching with the materials and in the way described by the materials. Mark and Fawn did not meet the minimum implementation to focus the case study and provide useful information. While Trisha was willing to participate in the data collection for this study, she showed little inclination to implement the practices so there was not enough to report to add to an explanatory framework; thus, only the cases of Leslie and India are presented. There was not enough in Trisha's case to report to add to an explanatory framework. These three teachers were excluded from the study due to constraints in their contexts; thus, only the cases of Leslie and India are presented.

time. The consent forms placed special emphasis on the confidentiality of student and teacher responses. Students and parents were assured in the consent forms that names would not be attached to individual responses, and that pseudonyms would be used in the event that researchers identified a direct quotation from the classroom observations for use in publication, presentations, and reports.

I visited both Leslie's and India's schools three times before commencing with the first video-recording. The goal was to have the students accustomed to having unfamiliar visitors in the classroom with the hope that when the video cameras arrived, the video-recording would not be too much of an interruption. These observations were also useful in establishing a storyline and capturing the nuances of their classes. Before each visit, I sent an e-mail to ask the teacher for permission to visit.

## **Data Collection**

### **Summary of Data Collection**

Data for the study were collected during the fall semester of the 2009-10 academic year. Multiple modes of data collection (Bogdan & Biklen, 2007; Creswell, 2007) were employed for this study: direct observations, post-observation conferences (interviews), and document analysis. Each mode is explained further below.

#### **Direct observations and video data.**

Direct observations served as the primary source of evidence for the study. I observed each teacher's classes eleven times during the semester. This totaled approximately 900 minutes of observation data for each teacher. Five of Leslie's eleven classroom lessons were video-recorded, and six of India's eleven classroom lessons were video-recorded. Typically,

*Core-Plus* lessons are multi-day lessons. The video-recorded observations occurred twice during the semester; in late September and early November (for Leslie) and in early October and late November (for India). Three consecutive school days of video data were collected for both teachers, except for in late September with Leslie when two days of video data were collected.

Two researchers were present for seven of the eleven video-recorded observations. When two researchers were present, I took field notes and the other researcher managed the video-recording and equipment. The camera was arranged to capture the teacher's perspective as much as possible and interactions with students and between students while the teacher is facilitating cooperative learning. When I wrote field notes, I captured the timeline of events during the lesson, noted important conversations, and marked any instances that warranted further discussion during the post-observation conferences (explained later). I, as the note-taking researcher, paid attention to and recorded events and occurrences such as how many students volunteered to participate, who participated, and made notes about the quantity and quality of student-to-student interactions. I also noted instances to return to during data analysis by recording the time stamps. When I was the only researcher present, I managed the video-recording equipment and took notes of events to revisit during analysis. I was the only researcher present during the observations that were not video-recorded. During those observations, I took field notes and reflected on the observation afterwards in an electronic journal.

#### **Post-observation conferences.**

In line with the idea that “meaning is socially constructed by individuals in interaction with their world” (Merriam, 2002, p. 3), the second data collection technique employed was the interview. According to Yin (2003), the interview is one of the most important sources of case study information. The interviews in this study are referred to as post-observation conferences (Hufferd-Ackles et al., 2004) to highlight that they were conducted more like “guided conversations” (Yin, 2003, p. 89) than “structured queries” (Yin, 2003, p. 89). They were employed to examine how the teachers perceived their progress in facilitating a mathematics discourse community in their classrooms, improving their use of formative assessment in teaching, and otherwise moving along with their action plans. Throughout the post-observation conferences I, as Yin suggests, both followed my own line of inquiry and asked the actual questions in an unbiased way.

During each video-recorded observation, the teachers participated in a post-observation conference (Hufferd-Ackles et al., 2004). Each post-observation conference began with a description of how the conference would proceed. During these conferences, teachers viewed excerpts of their video-recorded teaching and responded to open-ended questions about their instructional decisions during the video segments selected (Hufferd-Ackles et al., 2004). During the conference on the first day of the first observation, the teachers responded to a series of introductory questions about their teaching careers, mathematics backgrounds, beliefs about teaching and learning mathematics, and their feelings toward reform mathematics and *Core-Plus*. The post-observation conferences were recorded using a digital voice recorder and later transcribed to be used as a data source for analysis. A semi-structured interview schedule (see Appendix B) with open-ended questions

was used during the post-observation conferences. A semi-structured interview was chosen because it promotes an experience in which the teachers' viewpoints are more likely to be expressed than in a standardized interview or questionnaire (Flick, 1998). The interview schedule comprised questions to elicit teachers' recall of their thoughts while they taught the foregoing lesson. The interview schedule also comprised questions regarding their instructional practices, their use of the curriculum, their experiences and feelings using the curriculum, and their perceptions of influences upon their decisions.

After the series of introductory questions, the second part of the conference consisted of each teacher viewing video clips from a video-recorded classroom lesson. I selected excerpts of their video-recorded lesson prior to our conference and asked the teachers to reflect on the clips considering the math-talk learning community framework and their action plans and reflection sheets (see Appendix C and D) from the Summer Institute. Episodes during the classroom lesson during which the teachers were engaged in instructional practices relevant to the study were selected as the prompts for discussion during the second part of the conferences. The observations described in the previous section occurred in the teachers' classrooms and the video-recordings of the classroom lessons and the field notes taken were used to obtain stimulus material for the stimulated recall portion of the post-observation conferences.

Leslie's planning period was third period, and her fourth period was the subject of the research, so our post-observation conferences occurred the day following the video-recorded observations. India had second period planning, and her first period was the subject of the research, so our post-observation conferences occurred the same day as the video-recorded

observations. The teachers were also asked to consider the following two questions while viewing the video clips: What do you notice? What is your interpretation of what took place? (Sherin & van Es, 2005). The purpose of the interviews was to capture the teachers' experiences from their point of view, so it was important for me to allow their perceptions to guide our conversations. The questions were chosen to guide the conversations with the understanding that the conversations needed structure, but also needed to be driven by the participants, and not me. Rather than focusing on observable teaching activities, I also sought to gain insight into the ways the teachers made sense of their instructional decisions through triangulating data from the semi-structured interviews and my field notes (Paterson, 2000).

#### **Documents and other artifacts.**

In case studies, documents are used to corroborate and enhance evidence from other sources (Yin, 2003). Other artifacts that served as data for this study included three types of documents: content specialist observation reports, Table-of-Contents (TOC) logs, and teacher artifacts from the NCIM Summer Institute (these include the teachers' action plans). These data were a source of analysis and provided details for the context of the study.

#### **Content specialist observation reports.**

The content specialists, Linda and Margaret, associated with this project were two experienced teachers who had successfully taught using the *Core-Plus* curriculum materials. Linda and Margaret had both taken time off from teaching to spend time with their young children while they served as content specialists for the project. The NCIM supervisors identified and hired them to work as content specialists. They provided a minimum of one-day monthly visits to the teachers and assist the teachers implementing *Core-Plus*. During the

site visits, they provided customized mentoring and tailored their assistance to the teachers' needs. Both content specialists also served as facilitators for the Summer Institute, so their relationships with the teachers began to form at the Summer Institute. At the beginning of the school year, the content specialists visited the teachers, determined the needs of each teacher, and started to make plans for how to deal with some of their needs (Krupa & Confrey, in press). One of the content specialist duties was to submit a report (see Appendix E) for each of their visits with each teacher. For each visit, the content specialists contacted the teachers to arrange their site visits and they followed up with the teachers between visits. The NCIM research and evaluation team created the content specialist observations report protocol during the first year of the project and then adapted it for the 2009-10 academic year in response to the evaluation data from prior years. In the reports, the content specialists made comments about the lesson taught, recorded observations of the teachers' interactions with the students, and detailed what they work on with the teachers during their visits. These reports were compared to the other data collected in past years in an attempt to establish linkages between any teacher changes and the assistance provided by the content specialists and to corroborate findings from the observations and interviews.

**TOC logs.**

The participating teachers were also asked to complete Table-of-Contents (TOC) logs (see Appendix F and G) in which they documented which sections of the textbook they taught that semester. The logs were distributed to the teachers at Summer Institute the beginning of the semester the teachers were asked to return the completed logs at the end of



each academic quarter. The completed logs provide some indication as to the extent to which teachers implemented the curriculum materials.

### **Teacher artifacts from the NCIM Summer Institute.**

During the NCIM Summer Institute, the teachers completed a content knowledge assessment (see Appendix H) on the first day of the Summer Institute (pre-test) and on the last day of the first week of the Summer Institute (post-test). The content knowledge assessments were developed by the NCIM research and evaluation team. The content knowledge assessments covered mathematics material spanning the topics of the first three courses of *Core-Plus*. Information from these assessments may be gleaned about the teachers' level of mathematical content knowledge. These data were also used to investigate differences between teachers' instructional practices based on level of content knowledge (as measured by the content knowledge assessments.) The teachers also participated in reflective activities during the Summer Institute. For example, toward the end of the week they were asked to complete an action plan for working on a self-selected area discussed during the Summer Institute. Copies of these artifacts were made so that they could be used as a data source.

### **Methods of Data Analysis**

In this section, I describe how I analyzed the data collected for this study. As with many case studies, the data collection and data analysis for this study overlapped (Eisenhardt, 2002). Data were collected and used from multiple sources for this study's analysis. All sources of data were reviewed and analyzed together so that the study's findings would not be based solely on one source of data, but instead on the convergence of information from

different sources (Yin, 2003). In accordance with most qualitative data collection and analysis, the process was inductive in nature.

Informal data analysis occurred simultaneously with data collection. Following the suggestion of Merriam (1998), a preliminary analysis was conducted after each observation and interview. Information from one source of data was compared with information from another source of data throughout the data analysis process (Paterson, 2000). I used field notes, which Eisenhardt describes as a running commentary about what is happening in the research to help with the overlap of data collection and analysis. When taking field notes I recorded any impressions that occurred and I pushed my thinking by asking myself questions like, “What am I learning?” and “How does this case differ from the last?” (Eisenhardt, 2002, p. 15). I made notes when instances occurred that were related to the research questions and would help with the identification of themes later.

Once all the video data was collected, analysis began of the teachers for which two sets of video-recordings of implementation of lessons existed. I processed the video data using Powell, Francisco, and Maher’s (2003) model of video data analysis. Before any analysis occurred, I viewed each video-recording without attempting to interpret events or draw inferences. Every three to five minutes, I recorded a description of the events in a table. Critical events, which were defined as any instances during which the teachers were implementing techniques from the Summer Institute and demonstrating components of the math-talk learning community were identified and strategically transcribed.

After transcribing the interview data and the descriptive summaries of the video data, I undertook open coding of those data and the field notes, from which themes emerged

related to the challenges the two teachers faced during implementation of *Core-Plus* (Grbich, 2007; Stake, 1995). In this process, I allowed the “data to speak for themselves” (Grbich, 2007, p. 32) as opposed to forcing the data to fit predetermined themes. The critical events identified through video data analysis were also compared to the different levels within the four components of the Math-Talk Learning Community framework to provide illustrations of the teachers’ development of a discourse community and otherwise progress according to their action plans. Examples are included in response to the second research question as evidence of the development of a discourse community through the various levels within the framework. Excerpts of discussions are also included in the presentation of the findings and answers to the research questions. Any actions of the teachers or students appear in italics within brackets. Any commentary I added does as well. The data from the TOC logs and content specialist observation reports were analyzed to corroborate and enhance evidence from the direct observations and post-observation conferences.

### **Storing the Data**

Following each visit, video- and audio-recorded data were downloaded and stored on secure servers at the Friday Institute for Educational Innovation. Backup recordings and original work products were stored securely in the researchers’ office and an external hard drive. Video-recorded data will be retained indefinitely, as the data may be re-examined later for insights into additional research questions that arise subsequent to this project. Some of the video-recordings were used for the 2009-10 NCIM professional development activities with the teachers’ consent.

### **Appropriateness of Research Strategy**

A case study methodology was chosen to answer the research questions (Merriam, 2002; Stake, 1995; Yin, 2003). Yin (2003) defines a case study as “an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident” (p. 13). For this study, a case was defined as a teacher in her classroom implementing *Core-Plus* the semester after having participated in the NCIM Summer 2009 Institute. Furthermore, case studies are needed when the researcher is interested in understanding complex social phenomena, and in this study, focus on documenting how program theories and components of a particular curriculum play out in a particular real-life situation. In this study, student test scores would not adequately shed light on the teachers’ instructional decisions and practices and survey data is less than ideal for investigating this phenomenon.

Nathan and Knuth (2003) recommend that the complex nature of classrooms and schools be taken into account when discussing the challenges of implementing reform. The situation with schools is especially complex within the larger context, which includes heightened accountability and increased awareness of rising dropout rates and inadequately prepared students.

According to Yin (2003), the technical definition of case study includes that “the boundaries between phenomenon and context are not clearly evident” (p. 13). He further asserts that researchers should use the case study method when they want to deliberately deal with contextual conditions because they believe the details of the context will be highly relevant and significant to the phenomenon of study. The technical definition of case study

also includes that the case study inquiry “copes with the technically distinctive situation in which there will be many more variables of interest than data points, and as one result relies on multiple sources of evidence, with data needing to converge in a triangulating fashion” (pp. 13-14).

A better understanding of the process through which teachers adjust to teaching *Core-Plus* is needed. Teachers with little experience teaching with curricula like *Core-Plus* will need assistance making the transition from their more traditional instructional practices. This study is an exploration into how teachers make the transition while participating in the NCIM professional development. The case study method was chosen for this study in light of the belief that the larger contexts of the teachers, school, and communities will have an impact on how the teachers function the year following their participating in the NCIM Summer Institute.

Yin (2003) maintains that the researcher collecting data for the case study cannot always predict what will become relevant during data collection because the data collection does not follow a formal plan. As suggested by Yin, I continually reviewed the evidence, asking myself “why events or facts appear as they do,” (p. 59) realizing that my judgments might induce a need to search for and collect more evidence.

Case study is appropriate for this study also according the NRC’s discussion of case study as discussed in the 2004 curricular evaluation report, which states that knowing how effective a particular curriculum is and under what conditions is valuable. Case studies are particularly valuable when evaluating curricular programs because they “articulate the underlying mechanism by which curricular materials work more or less effectively and

[identify] variables that may be overlooked by studies of less intensity” (p. 60). Case studies also provide insight into factors that are not visible just by comparing student achievement scores. Also according to the NRC report, case studies examine how curricular effects are obtained. In order to learn “how” certain factors cause the intended effects, studies should be conducted to help understand the processes and mechanisms at play. Another benefit of conducting case studies on how teachers implement curricula is that the findings may provide useful information on how program components interact with implementation factors in the classroom. This information can lead to identifying potential explanatory variables to be included in future evaluations (NRC, 2004). The case studies included in the report showed how important the level and quality of professional development are in considering the level of the curricular program’s implementation. It is especially important when changes in teachers’ beliefs, understandings, and practices are required to implement the curriculum.

This study employed qualitative data techniques because they were best suited to answer the research questions. Ritchie and Lewis (2003) suggest that researchers should employ qualitative methods to “address research questions that require explanation or understanding of social phenomenon and their contexts” (p. 5). They further assert that qualitative methods are especially appropriate for exploring complex issues and studying processes occurring over time (Ritchie & Lewis, 2005). This study collected data in “a natural setting sensitive to the people and places under study” and used inductive data analysis procedures, establishing patterns in the data (Creswell, 2007, p. 37). Because of the interest in relating changes in teachers’ instructional practices to their participation in NCIM and specific elements of the professional development, it was important to seek the meanings

and perspectives of the teachers (Creswell, 2007). The post-observation conferences were employed to obtain the voices of the participants.

### **Strategies for Validating Findings**

Validity and reliability can be addressed in a number of ways when using qualitative data. Creswell (2007) presents several validation strategies. Instead of using the term validity, several qualitative researchers suggest the use of terms like trustworthiness, credibility, confirmability, and data dependability (US General Accounting Office, 1990). Strategies were employed to enhance the integrity of the data collection. Using multiple data collection techniques serves to enhance the authenticity of findings (Merriam, 2002). Denzin (1970) refers to this form of triangulation as “data triangulation,” which is a means for the strengths of one data collection technique to compensate for the weaknesses of another (as cited in Merriam, 2002). Yin (2003) argues that the need for multiple sources of evidence in case study research surpasses the need to do so with other research strategies. Furthermore, he argues that the greatest advantage to using multiple sources of evidence is the development of “converging lines of inquiry” (p. 98).

Maintaining the chain of evidence is also a tactic used to enhance the reliability of the case study findings (Yin, 2003). Reliability is a measure of the extent to which an investigator would arrive at the same case study findings if he or she were to follow the exact same procedures as described in this study (Yin, 2003). Yin stresses that replication in this sense is conducting the same study again not on “replicating the results of one case by doing another case study” (p. 37). In terms of reliability, the objective was to minimize the errors and biases in this study. The procedures employed in this study were carefully documented to

increase the study's reliability. Yin suggests that in handling the reliability issue, the researcher should "conduct research as if someone were always looking over [his or her] shoulder" (p. 38). This study was conducted with the consideration that another researcher should be able to repeat the procedures and arrive at the similar results. Stake, however asserts that, "The quality and utility of the research is not based on its reproducibility but on whether or not the meanings generated, by the researcher or the reader, are valued." (p. 135)

Generalizability, also referred to as external validity (Merriam, 2002), describes the extent to which findings can be applied to other settings. Establishing external validity in this study should be thought of differently than with studies employing quantitative data collection techniques. Ritchie and Lewis (2003) make a distinction between inferential generalization, which is a "proposition to settings and people other than those studied" and theoretical generalization, which "applies constructs developed in a study to the generation and refinement of theory" (p. 29). Similarly, Yin (2003) declares that findings of case studies are generalizable to theoretical propositions and not to populations or universes. Yin uses the term analytic generalization as opposed to statistical generalization. Rich, thick description as described by Merriam (2002) has been used to ensure external validity in the qualitative sense in this study.

### **Anticipated Ethical Issues**

I sought the approval of the North Carolina State University IRB before commencing data collection for the purposes of this study. There were no major risks associated with participating in this study, and the benefits included becoming more sensitive to classroom interactions between themselves and their students, or among their students. Teachers as an



indirect result of their own personal reflection, during interviews on their thoughts, academic progress, or interactions, might gain insight into their own knowledge or self-perception that may accrue indirectly to their personal, academic, or professional benefit. Individual teachers and students were assured in the consent forms that they would not be identified by name. They were also assured that if direct quotations of individual responses were included in the analysis, they would be attributed to pseudonyms for the sake of confidentiality.

### **Subjectivity Statement**

According to Ladkin (2005), “critical subjectivity encourages inquirers to notice the particular frames of reference they bring to any inquiry arena, including, among others, their political, racial, cultural, or gendered orientation” (p. 116). For this reason, I present my background and orientation. I am twenty-eight year old female who self-identifies as African-American or Black. My mother is a middle school mathematics teacher, and my father has worked at the local paper mill all of my life. Both of my parents possess moderate to liberal political views and identify with the Democratic Party. I was raised in a middle-class family, and I attended public schools in Glynn County, Georgia through 12th grade. After graduating from high school, I enrolled in a private liberal arts women’s college in Georgia.

As a middle and high school student, I excelled in mathematics, but lacked confidence in my abilities. I earned a Bachelor of Arts in Mathematics, and I believe I declared Mathematics as a major because of my experiences in my first mathematics classes at the women’s college. After college, I taught middle school mathematics at an affluent independent school in a southwestern state before beginning graduate school. While teaching

in this environment, the disparities in educational opportunities for children and the correlation to their families' socioeconomic or social status became profoundly clear. I view education as a life-long journey, and I consider myself an advocate for all children, but especially for Latino, Black, and American Indian students, students from low-income families, and students who struggle in school and seem to "fall through the cracks." I believe a family's financial resources should not limit a child's access to high-quality educational experiences and that adequately preparing young people to become successful and productive members of society is critical for sustaining our democracy.

It was in college that I became a more confident mathematics student. In graduate school, I continued to tutor and substitute in mathematics classes to share my love of mathematics with students. I find I am saddened when young women express their aversion of mathematics, as I believe there exists a strong relationship between students' attitude towards mathematics and their prior experiences in mathematics classes and with mathematics teachers.

It was important that I made a conscious attempt to bracket aspects of my subjectivity that may affect my interpretation of any data collected as a part of this study. These aspects may include my own previous experiences as a teacher of mathematics, experiences with professional development, experiences as a member of the research and evaluation team, and feelings about traditionally underserved students. It is also important to reveal that during the first week of the 2009 Summer Institute, I assumed no evaluation duties and that I participated in the activities and discussions with the teachers in one of the two Course 1 rooms. I introduced myself as a graduate student who was studying the teachers' experiences

in the professional development. I have presented potential points of my subjectivity because of my current, but ever-changing, belief is that we know “objectively” through our subjectivity, or in other words, I believe that “there is only objectivity-for-subjectivity” (Ladkin, 2005, p. 121) and that “subjectivity must be understood as inextricably involved in the process of constituting objectivity” (Ladkin, 2005, p. 120).

### **Summary**

This chapter provided a detailed look at the methods that were employed in this study. This dissertation study employed observations, interviews, and document analysis as the data collection methods. The chapter has provided a description of data analysis procedures and has discussed the appropriateness of the study’s design and methods. The chapter concluded with a discussion of ethical issues and potential limitations of the study.

## CHAPTER FOUR

### FINDINGS

This chapter begins with a description of the NCIM professional development model. Evaluation results from the 2009 NCIM Summer Institute are presented to provide a sense of how the entire group of participants perceived their experiences in the Institute and to help situate the study in that context. Next, I review the purpose and research questions guiding the study, and I describe the teachers included in the study based on information they provided during an interview and demographic information about their schools and districts. I complete this chapter by presenting the findings from the classroom observations, interviews, and content specialist reports organized by research question. Quotes from the teachers are included to illustrate their perspectives and feelings.

#### **The North Carolina Integrated Mathematics (NCIM) Professional Development Model**

Teachers included in this study participated in the NCIM professional development, which was developed to support and help increase the knowledge and skills for a cadre of North Carolina secondary mathematics teachers implementing *Core-Plus*. The components of NCIM included a team of content specialists who customized professional development by making monthly visits and providing on-site coaching, a website, two one-day follow-up conferences each year, and a residential Summer Institute. The focus of this study is the Summer Institute and content specialist visits.

Data collected from the content specialists reports and Summer Institute evaluations during the first two years of the project were used to revise the current practices of the model to better suit the teachers' needs (Confrey, Maloney, & Krupa, 2008; Confrey, Maloney, &

Krupa, 2009). An overall evaluation report on the content specialist visits and the 2008 Summer Institute indicated that the teachers needed assistance in a few areas. Observation reports from the content specialists showed the following concerns about the teachers' implementation of the curriculum: the teachers have inadequate content knowledge to implement the curriculum, class time is used ineffectively to provide warm-ups, formative assessment, closure, and lack of student participation (both whole-class and in groups). The teachers' weaknesses in mathematical content knowledge and pedagogical practices both resulted in less than ideal implementation of the curriculum. The content specialists suggested that the Summer Institute include sessions focusing on classroom management and effective cooperative learning (Confrey, Maloney, & Krupa, 2008). Participating teachers were also found to lack trust in the curriculum and the confidence to implement this curriculum successfully (Confrey et al., 2008). The project directors and research team collaborated to create a Summer Institute to address the teachers' weaknesses.

### **The 2009 NCIM Summer Institute**

#### **Week one.**

During the first week of the 2009 Summer Institute, fifty-nine participating teachers experienced *Core-Plus* from the student perspective. The Summer Institute consisted of four daily classes (i.e., two for Course 1, one for Course 2, and one for Course 3) taught by trained national facilitators and experienced North Carolina teacher leaders. There were two Course 1 classes because most of the participants were new to *Core-Plus* or looking for an introduction to the curriculum. Twenty-three teachers were in each Course 1 class. Each day the participants had a morning and an afternoon session, and there were special topic

afternoon sessions during the middle of the week. At the end of each day, the participants completed an evaluation of the day's activities, and then at the conclusion of the week, they completed a final evaluation. The participants were also asked to complete a background questionnaire at the onset of the Institute, and from those questionnaires, we learned that of the fifty-nine total participants, only ten had taught *Core-Plus* before. With respect to academic degrees, 73% held a Bachelor's degree only and 27% held a Master's<sup>6</sup> degree.

In general, the participants provided positive feedback about the Summer Institute's first week. One complaint was that the pace of the week was too fast and that the participants spent too much time in their seats. On the other hand, the participants enjoyed working with the computer software accompanying the textbook, CPMP-Tools®. They also enjoyed having visuals and props to help them visualize the material they were learning. The participants for the most part indicated that the Summer Institute made them more committed to using *Core-Plus*. Regardless of whether they were inclined to implement the curriculum, many teachers responded that they planned to use more investigations in their teaching and incorporate more hands-on activities that lead to student discovery of key topics. They also planned to step away from the traditional classroom arrangement of students in desks in rows and move toward increasing the amount of collaborative group work. Overall, the teachers appeared eager to return to their classrooms to implement what they had learned in the Summer Institute. Accompanying their enthusiasm, though, were concerns about how to make it all come together.

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<sup>6</sup> The Master's degrees recorded by the participants were in the following areas: Mathematics Education, Curriculum & Instruction, School Administration, Mathematics, Secondary Mathematics, and Middle Grades Mathematics.

The teachers who planned to implement *Core-Plus* the upcoming school year anticipated challenges in two major areas: relinquishing control (shifting from a teacher-centered classroom to a student-centered classroom) and planning for the course. Most of the participants responded on the evaluations that they felt the Summer Institute prepared them for implementing the curriculum, but they would have appreciated more time to explore the curriculum and ask questions. Some participants felt like there was too much information to process in a week's time. They did express that they found value in experiencing the curriculum from the student perspective, and they responded that having the opportunities to work through the investigations and to anticipate student responses and misconceptions was also valuable to them. The participants also enjoyed collaborating with other teachers from schools across the state.

**Week two.**

Twenty-six teachers participated in the second week. Seven of these teachers taught at the NC-STEM partner schools and were involved with the other components of the NCIM project. The second week of the Summer Institute was designed to provide professional development focusing on pedagogical techniques that the evaluation team viewed as compatible with *Core-Plus*. Based on the analysis of the content specialist reports, the team identified concerns to address during the Institute. The focus of the second week was developing and promoting effective classroom discourse (Herbel-Eisenmann, 2009; Hufferd-Ackles et al., 2004), formative assessment, connections to the North Carolina Professional Teaching Standards, planning for lessons, and pacing for the year. The facilitators guided the teachers in lesson planning, and the teachers were offered numerous opportunities to reflect

on their practices and collaborate with other teachers. At the conclusion of the second week, the participants planned and taught a portion of a *Core-Plus* lesson in groups of three. On the final day of the Summer Institute, the teachers created action plans intended to help them improve their practice.

The participants found the discourse discussions<sup>7</sup> most beneficial, according to the participants' responses on the evaluations (Confrey et al., 2009). The participants viewed the session on time management strategies favorably as well. The 2008 evaluation report indicated that the participants felt they needed more time to discuss planning, so the 2009 Summer Institute included more time for the teachers to focus on planning. The participants responded that this change was beneficial. The evaluation report further showed that the teachers enjoyed valued collaborating with other teachers (Confrey et al., 2009).

Responses from second-week participants indicated that some of the criticisms of first-week only participants would have been eliminated had they attended the second week. Second-week participants noticed differences between the two weeks of the Summer Institute. One of the main differences they noticed was that the first week focused on the mathematical content, while the second week focused on applications of implementing *Core-Plus*, including the teacher's role in the classroom, fostering discourse, and implementing effective teaching strategies. Some of the teachers responded that the second week of the Summer Institute made them feel more confident about implementing the ideas they learned

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<sup>7</sup> The teachers considered the math-talk learning community discussion beneficial and found the opportunity to locate their teaching behaviors within the levels of the Math-Talk Learning Community framework valuable because the Summer Institute was a "nonthreatening" environment. The activity made the participants aware of their place in the trajectory and made them think about how they could improve their practices to improve the math-talk in their classrooms.



in the first week. They also felt more comfortable to share and collaborate during the second week. A few reasons might explain the increased feelings of comfort. There were fewer participants, most of whom were current implementers or either scheduled to implement the upcoming academic year. The increased comfort might also be attributed to the week's change in focus.

Regardless of whether teachers planned to implement *Core-Plus* the upcoming year, they planned to make changes in their instruction. They planned to incorporate a more student-centered environment including using investigations and advanced questioning techniques and transition into a facilitator role, having less teacher-talk and more student-to-student talk. The teachers also planned to incorporate the strategies they learned for managing students working in groups. Some of the second-week participants who would continue to teach using traditional curriculum materials indicated that they planned to incorporate the techniques they learned in the Summer Institute nonetheless. Some non-implementers of *Core-Plus* anticipated resistance from colleagues. Other concerns of the teachers were learning to manage student groups and having inadequate resources.

### **Purpose and Research Questions for the Study**

The purpose of this research study is to investigate the effect of NCIM on teachers' instructional practices the 2009 fall semester. This study was a qualitative case study, as I sought greater understanding of how the teachers responded to the professional development and because this study addressed research questions that required understanding a social phenomenon and its context (Stake, 1995; Ritchie & Lewis, 2003). This study describes teachers' experiences implementing *Core-Plus* after participating in the 2009 Summer

Institute as they sought to implement a “math talk” community. I was interested in how the teachers implemented the curriculum and the ideas presented in the Summer Institute and any challenges or obstacles they encountered. These findings provide insight into why implementation variation of *Core-Plus* might exist.

Two research questions guided this dissertation study:

- (1) What challenges or obstacles, if any, do the teachers encounter while using the *Core-Plus* curriculum materials and attempting to apply the ideas presented during the 2009 NCIM Summer Institute?
- (2) How do teachers attempt to develop a math-talk learning community after participating in the 2009 NCIM Summer Institute?

### **Participants and Context**

#### **Leslie.**

Leslie was a young, White female, who had recently graduated from a state school with a Bachelor’s degree in middle grades science and mathematics, with teaching certification for grades six through nine, mathematics and science. The principal at Sycamore High School (SHS), a part of the Sycamore County school district, hired her during the summer of 2009, days before the Summer Institute. SHS was an early college high school located in the eastern part of the state. During Leslie’s first year of teaching, there were only ninth through eleventh grades, and she taught four sections of Course 1 to classes of only freshmen, who had never experienced an integrated mathematics curriculum before. The Sycamore County Schools district was composed of 40% White students, 30% Black students, and 30% Hispanic students and had a graduation rate of 71.9% the previous year,

and 69.2% of the students qualified for free or reduced lunch. Teachers at SHS began implementing *Core-Plus* during the 2007-2008 school year when the school opened, and all students used the same curriculum. Leslie's principal had also decided that all ninth graders would enroll in Course 1 regardless of their middle school mathematics experiences. He also decided that the freshmen at SHS would remain together as a class as they transitioned from class to class on their schedules. Leslie joined one other mathematics colleague who had begun teaching there in January of 2009. SHS had experienced significant turnover and inconsistency in their mathematics department before both of them were hired. The faculty at SHS participated in professional learning communities on Wednesday afternoons each week, and the teachers were available for tutoring for students on Tuesday and Thursday afternoons.

Leslie's prior teaching experience included a month-long interim position that she began after end-of-course testing and substitute teaching for a year and a half. She had also held a position at a non-traditional alternative school in the area, where she taught various mathematics courses in what resembled a one-on-one tutoring situation in which she had individual plans for each student because students enrolled in the school throughout the year. Leslie described herself as a student who was always "good at mathematics," but explained that mathematics was not always her favorite subject. She said she had experienced relatively effortless success in mathematics and that influenced her decision to concentrate in mathematics and science. Before NCIM, she had only experienced traditional mathematics curricula. She felt as if she had learned more about mathematics using *Core-Plus*, and that it was her first time seeing the "different stuff you can do with math." She said the curriculum

had helped her gain a new understanding of mathematics and a new appreciation for mathematics (Interview on 9/24/2009).

Leslie said she felt students learned mathematics best by “doing and relating to real life.” She added that, “Some students either get math or don’t get it. They struggle with it.” She felt that if real-world applications could be made to the mathematics the students would be more likely to retain the information. Leslie felt that her role as the teacher was to guide children and help them, “not to tell them what to do and then do it, [but] to guide them to the understanding,” and “give cues and questions” (Interview on 9/24/2009).

Each teacher’s feelings toward the curriculum are important because they provide a sense of them as teachers and further describe the context in which they were enacting the curriculum. Leslie had positive feelings towards *Core-Plus*. She described *Core-Plus* as “awesome.” She enjoyed that it set up real world situations, but also agreed that the book required some getting used to. She said, “If you first look at the book, you’re like oh Lord what is this?” She added, “If you believe that the teacher’s role is to guide, it sets that up for you” (Interview on 9/24/2009).

Leslie thought she was very comfortable with the curriculum, but that she did have to work through the lessons before assigning them to the students. She attributed her comfort to having participated in the two weeks of the Summer Institute. She said she enjoyed teaching consistently with the *Core-Plus* curriculum. She said during the first post-observation conference, “Had I not been at the workshop I’d not be very comfortable and I’d be very hesitant. I wouldn’t even know how to work through this book. I think you need to be taught

how to use this stuff if you've never done it this way. Not math this way. It's a lot harder” (Interview on 9/24/2009).

Leslie randomly selected her fourth period class for the research conducted in this study. The class was comprised of twelve girls and seven boys. Because her students spent the whole school day with each other in their other classes as well, they appeared to be very comfortable with each other.

### **India.**

India was a young, African-American female in her second year teaching at Morrison STEM High School (MSHS). MSHS was a high school with a STEM focus and was located within Morrison County Schools district, which was comprised of 45% White students, 42% Black students, and 12% Hispanic students. MSHS was also started during the 2007-2008 school year, and thus only had students in the ninth, tenth, and eleventh grades during the 2009-2010 school year. During the 2008-2009 school year, the Morrison County Schools district recorded a graduation rate of 72% and that 61.8% of the district's students qualified for free or reduced lunch. India also graduated from a college in the state and began teaching at MSHS the year after she graduated.

India said she had always enjoyed mathematics. She remembered deciding that she wanted to be a math teacher in the seventh grade when she “had a teacher that showed [them] multiple ways of doing things.” She said that her feelings toward mathematics had not changed, but that since becoming a teacher, she had “a hard time understanding students who have a hard time with math” and that she struggled with how to reach some of the struggling weaker students who “did not try.” India felt that students learned mathematics best “when

they can talk.” She added that she felt that students would learn from each other’s approaches to solving problems when allowed the opportunity to talk to each other. She stated in the first post-observation conference that,

I feel like when I was up at the board, it was a part of a lecture, and you lose the kids when you’re at the board all the time. So if there are things they can do I let them come to the board because they’re more engaged if there are students at the board (Interview on 10/09/2009).

India viewed her role as a facilitator – “to walk around and make sure they’re on task, help clarify answers or questions.” She explained that it was sometimes difficult for her students to adjust to her behavior. She stated, “It’s kind of hard for them sometimes, because I answer a question with a question. I think it’s more beneficial to probe them than to tell them the answers” (Interview on 10/09/2009).

India was also eager to share her feelings toward *Core-Plus*. India said she loved the first course because she felt like it included more activities. She had only taught the first course once, but she described her experience as “not that hard.” She expressed similar feelings about the second course. She said the third course had been the most difficult one to teach because she did not like geometry. She said that breaking the material down for the students was a struggle and that it was sometimes difficult to understand the questions asked in the book. She made the following comment about how she felt her students learned, “If they can’t draw it or put their hands on it, they really don’t understand. If they don’t see it right there, they shut down. It’s been hard just to understand the material myself, but to try to

relate it to the kids in way so that they understand. That's the most difficult part about it" (Interview on 10/09/2009).

India loved that the text required the students to read, but she also felt like the higher courses were not as interactive as the first course." India also said there were parts of the book that she did not like as much as others and parts that she felt could use more examples. She gave an example of the matrices section. She criticized, "There's really nothing in there for them to get an understanding of what to do. Maybe a couple, and I feel like with matrices you have to practice if you want to learn how to do them by hand." India covered matrices during one of the video-recorded observations and her students worked on worksheets produced by a software program she used to produce worksheets for the students to practice. She said she used these worksheets when she felt like the students needed more practice with a topic (Interview on 10/09/2009).

India taught three sections: a semester-long Course 2, a year-long Course 3, and a semester-long Course 3. She selected her first period class, the semester-long Course 2 section. That class was composed of freshmen, sophomores, and a few juniors, including one who was repeating the course. There were six girls and twelve boys in her class, and she described her class as a male-dominated class, in which the boys were more vocal than the girls. Her students appeared accustomed to a routine: they entered the classroom each day, took their seats, and looked at the Promethean Board for their warm-up activity or do-now. They started working on their own, but sometimes at the encouragement of India, and when it was time to review the do-now, they knew to focus on whoever led the discussion. They

placed their warm-up activities in their folders and waited for India to give the next instructions.

India also felt like it was difficult to work with that class because she had inherited several students from a colleague whom she felt had not adequately prepared the students for the next course. She also expressed concern over having students who had not had mathematics for six months because of the semester schedule of some of her students.

### **Presentation of Findings**

#### **The Teachers and Reflection**

The post-observation conferences including the reflection component of viewing clips of the teachers' instruction make this study unique. Before presenting the answers to the research questions, I present a description of how the teachers responded to the reflection activities in the study. I include this perspective because this part of the data collection process influenced the outcomes. Instead of relying solely on classroom observations, I sought to obtain the teachers' perspectives. Reflecting in this way was new for both teachers, as they had not watched videos of themselves teaching before.

Even though the teachers attempted to incorporate reflection into their routines, the only times they engaged in reflective activities to this extent was during observation visits with me. India said that she had not had the opportunity to practice reflecting much in college and that the arrangement of her school day (i.e., that her planning period was in the middle of her classes instead of on either end) made it difficult to set aside time to reflect. The teachers had indicated previously on their action plans that they would assess their progress during the semester by either recording themselves. Another option was to have other teachers come in



for observations in a “rounds” model, and afterwards receive feedback. During the semester of data collection for this study, neither teacher had another teacher come in for an observation of that type. India’s principal observed her once during a visit.

During the post-observations conferences, some teachers gave the appearance that reflection was easier for them than it seemed for other teachers. The teachers talked freely during the first part of the interview when I asked them primarily questions about their educational background, feelings toward mathematics, philosophy of teaching, procedures for assigning students to groups, etc. When the teachers and I prepared to begin the conferences, I always told them that they should share any thoughts they might have while watching the video clips of their teaching. I also asked them to focus on two questions: (1) What do you notice? and (2) What is your interpretation of what took place? (Sherin & van Es, 2005). Getting them to talk during the video viewing portion of the interview was more of a struggle. I sometimes repeated questions or rephrased them as I probed the teachers’ understanding.

Neither Leslie nor India was particularly thrilled about watching herself on video. They said having to watch themselves made them nervous. While the teachers were not fond of the reviewing process, each described the experience as beneficial and positive. At the end of the first video viewing session, Leslie described the experience as “painful, but good.” She said, “I like to have any advice. Or even just watching this, of course, I can see little things that I need to work on. I mean it’s not fun to watch yourself, but it helps” (Interview on 9/24/2009). India described the process as weird, but she also felt like viewing the video-

recording was a good experience for her and her students. India made this remark about reflecting as she watched the videos:

I think it makes me aware of what I'm saying and how I'm explaining when I see it. That I could do some things a little bit differently. Or questions that the other kids might have and things like that (Interview on 10/12/2009).

It was particularly interesting to note the types of things the teachers mentioned during the video-viewing portion of the interviews. During the early interviews, the teachers noticed behaviors and actions such as their posture (i.e., standing in one place during most or all of the class period, playing with their hands) or their language (i.e., saying particular words too often when speaking). For example, when India watched herself on the videos, she noticed that she said the word, "Okay" often. She also commented on her facial expressions. Later during the first conference though, she not only followed-up on how often she was saying the word "okay," but she also noticed that she said "Okay," and then moved on, "not really checking to see if everyone is okay" (Interview on 10/09/2009).

The teachers on the second day of watching their video clips and reflecting said that they were more self-conscious of the things they noticed and discussed in previous interviews. Another observation was that the teachers sometimes made changes in their instruction over the course of the observations. These changes were sometimes influenced by their previous post-observation conferences during which they noticed an aspect of their instruction that they felt needed to change.

Although I did not assume an evaluative role as the content specialists did during my observations, my interactions with the teachers cannot solely be viewed as non-

interventionist. Instead, our interactions can be viewed as a form of professional development as well a means of conducting research. The changes the teachers made were influenced, either directly or indirectly, by their reflection exercises with me. It is important to note that these interactions affected the changes the teachers made in their instruction the outcomes of this study, and readers are advised to bear this in mind when reading and interpreting the results of this study. The conversations that resulted in our post-observation conferences, however, point to the need for giving teachers this kind of personalized attention when supporting them while adjusting to teaching mathematics in this new way. Moreover, just relying on observations as the sole source of data for the study would have resulted in less rich data.

In the next sections, I present the findings in the study as deduced from the classroom observations and our post-observation conferences. They are organized into two categories corresponding to each of the two major research questions. While I have identified themes and separated the findings accordingly, there is overlap between some of the themes. This overlap can be attributed to the nature of the curriculum and reform-oriented teaching.

**Research Question 1: What challenges or obstacles, if any, do the teachers encounter while applying the ideas presented in the NCIM Summer Institute and implementing the *Core-Plus* curriculum?**

As previous research study findings have shown, making the transition to teaching with *Core-Plus* presents challenges for teachers and the two case study teachers were no exception. It is important when reading the results, to keep in mind that these teachers are likely to have never experienced a mathematics classroom like the one fostered by the *Core-*

*Plus* curriculum as a teacher or as a student. The curriculum requires students to adjust to working together in groups and participating as active learners in class. The teacher also has to give up some control. For both teachers in this study, even with the help of the Summer Institute, challenges remained while implementing the curriculum once they returned to their classrooms. The challenges were similar to those anticipated by other Summer Institute participants as indicated in the 2009 evaluation report (Confrey et al., 2009). As will be shown, the case study teachers had to adjust to the structure of the curriculum materials and adapt to the investigation approach used by the curriculum. They also had to learn to promote collaborative learning among their students. Struggles with their own inadequate content knowledge, incorporation of technology, and planning and pacing, all complicated implementation of the curriculum. Perhaps the greatest adjustment was learning to facilitate discourse. In the following sections, I identify the categories of challenge and report on each describing how each teacher gradually encountered and reflected on them.

### **Adjusting to the Curriculum Features and Trusting the Curriculum**

A major distinction between traditional mathematics curricula and reform-oriented curricula like Core-Plus is in the delivery and presentation of the content. It takes time to become familiar with the structure of the curriculum. Before reporting on the teachers' practices, I review the structure of the *Core -Plus* curriculum, so as to help the reader interpret and place in context the specific instances of teaching practices. This discussion of the curricular program is included here to remind the reader of the program's elements as I explain how the teachers implemented the curriculum.

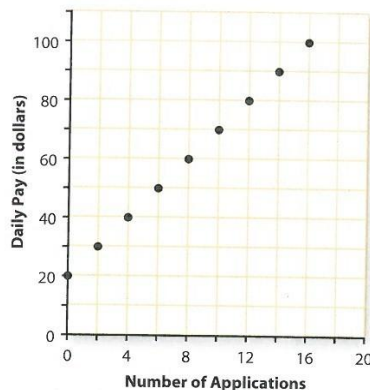
The classroom experience includes four phases – *Launch, Explore, Share and Summarize*, and *Apply*. The teacher introduces each lesson and launches class discussion through a problem situation called Think About This Situation (TATS) that sets the context for the students’ work to follow. Each lesson is framed by questions meant to focus the students’ attention on the lesson’s key ideas. During the TATS, the students discuss the problem situation as a class. The TATS is also viewed as a built-in opportunity to promote access and equity in mathematics classrooms (Hirsch et al., 2008). After the context is set, the students explore through group investigation. They work in small groups of four or two and explore more focused questions and problems related to the TATS. At the end of their exploration, students participate in a whole class discussion during which groups organize their thinking about the big mathematical ideas and share their insights with the entire class. This is the third phase, Share and Summarize. During the final phase, students work individually on assessment tasks in a section called Check Your Understanding (Coxford & Hirsch, 1996; Schoen et al., 1998; Schoen & Hirsch, 2003b, Coxford et al., 2008, p. xiv). These differences in structure add to teachers’ apprehension about the curriculum and make it difficult for them to trust the curriculum. These differences in structure add to teachers’ apprehension about the curriculum and make it difficult for them to trust the curriculum.

Leslie especially faced challenges in this area, and her struggles can be attributed somewhat to that she was a first-year teacher and did not have prior classroom teacher experience to draw upon. She recognized that it would be challenging to implement *Core-Plus* because it was her first time and her students’ first time experiencing a curriculum like *Core-Plus*. Some of her struggles with trusting the curriculum were evident during lesson

launches, when she went beyond providing a setting for the students to begin thinking about the upcoming lesson. An episode from an observation from September is provided as an example. Leslie stood before the students seated in groups and instructed the students to turn to Unit 3, Lesson 1, Modeling Linear Relationships, in their textbooks. She began the lesson by stressing its importance. In the textbook, before beginning the TATS, the students read: In the *Patterns of Change unit*, you studied a variety of relationships between quantitative variables. Among the most common were linear functions – those with straight-line graphs and that they show a constant rate of change and have rules like  $y = a + bx$  (Coxford et al., 2008, p. 150).

For example, Barry represents a credit card company on college campuses. He entices students with free gifts – hats, water bottles, and T-shirts – to complete a credit card application. The graph on the next page shows the relationship between Barry’s daily pay and the number of credit card applications he collects. The graph pattern suggests that *daily pay* is a linear function of *number of applications*.

Pay for Soliciting Credit Card Customers



According to the text, the lesson introduction was the following TATS:

**Think about the connections among graphs, data patterns, function rules, and problem conditions for linear relationships.**

- a) How does Barry’s daily pay change as the number of applications he collects increases? How is that pattern of change shown in the graph?

- b) If the linear pattern shown by the graph holds for other (*number of applications, daily pay*) pairs, how much would you expect Barry to earn for a day during which he collects just 1 application? For a day he collects 13 applications? For a day he collects 25 applications?
- c) What information from the graph might you use to write a rule showing how to calculate daily pay for any number of applications? (Coxford et al., 2008, p. 151).

Instead of guiding the students through the three TATS questions, she introduced the lesson by asking a series of questions geared to have the students explain the term linear. They even started a conversation about *slope*, which is not introduced until near the end of the first investigation. The purpose of the second investigation was to help sharpen their skills with finding rules for functions when given information in various forms. Leslie and her students engaged in the following exchange:

Leslie: So we're talking about linear relationships. What does linear mean?  
 Carlos: It goes in a straight line.  
 Leslie: It goes in a straight line. So, what does that mean, that it goes in a straight line?  
*[Several students respond.]*  
 Leslie: That's what it looks like, right? Does it have to look necessarily like this, that way?  
*[She demonstrates by placing her arm in front of her to symbolize the graph of a linear equation. Several students respond, "No."]*  
 Leslie: What else can it do?  
*[Several students respond.]*  
 Leslie: Can it go, I mean, what if it goes this way? What's it doing?  
*[Leslie demonstrated by placing her other arm in front of her to symbolize the graph of a linear equation with a slope of the opposite sign. Students respond, "Positive. Rising."]*  
 Leslie: It's rising. So what's positive?  
*[Students respond, "The slope." Here, Leslie directs the students to the term slope, which they had not introduced into the conversation yet, and which had not been introduced in the investigation.]*  
 Leslie: The slope. So what's it doing if my slope is positive? What's it doing?  
*[Students respond, "It's increasing."]*  
 Leslie: It's increasing. So, if. Does it always have to be increasing?  
 Students: No.

Leslie: No. What else can it do?  
Students: It can decrease.  
Leslie: It's gonna be a negative slope. So, it can be decreasing. So if we're looking at linear relationships, and I look at a graph, and I know it's linear, what do I know I'm going to see every time?  
Students: A straight line.  
Leslie: A straight line. I know I'm gonna see a straight line.

Perhaps Leslie felt the students needed more of a refresher of linear functions than provided by the textbook, but once the students responded that linear meant “straight line,” she went beyond that idea to a deeper explanation of the terms linear and slope, which would have come from the investigation. Leslie ended up “telling” the students about the situation instead of establishing a context for the students to think about the connections before beginning the lesson. From Leslie’s introduction of the lesson, much of the work is done before the students read the questions in the TATS, and Leslie has done most of the work. Instances like these, when teachers “teach” too much when the curriculum calls for a discovery approach make it challenging to compare traditional and reform-oriented curricula when the presentation of the texts has been altered in these ways.

The spiraling nature of *Core-Plus* also makes it hard to adjust to the curriculum. Evaluation data from 2008 (Confrey et al., 2008) showed that teachers had a hard time trusting the curriculum, especially in their first year teaching with *Core-Plus*. Some topics that teachers would typically cover completely in an Algebra 1 course, they may only introduce in Course 1. This facet of the curriculum really calls for the teachers to trust the curriculum and is especially a concern during a teacher’s first year teaching with the



curriculum. The evaluation results indicated that the teachers who participated in the 2009 Summer Institute anticipated that they would struggle with trusting the curriculum.

Important elements of the curriculum were highlighted in the Course 1 class at the Summer Institute. Even with this emphasis at the Summer Institute, because the teachers are accustomed to being the source of mathematical ideas in their classrooms, it can be difficult for them to introduce some concepts and then let them go as the textbook suggests or just present a situation for the students to begin thinking about the lesson without teaching. In traditional mathematics classrooms, the teachers are likely to be more accustomed to developing topics more completely within one lesson.

The *Core-Plus* materials emphasize sense-making for students, and that “through investigations of real-life contexts, students develop a rich understanding of important mathematics that makes sense to them” (Coxford et al., 2008, p. xi). Another feature is its emphasis on mathematical modeling. In the example just presented, Leslie’s choice of questioning during the introduction of the lesson precluded the students’ making connections between the Patterns of Change unit (Unit 1) and the Modeling Linear Relationships unit (Unit 3) because the teacher directed most of the lesson introduction.

Leslie attended the 2009 Summer Institute, but participated in the Course 2 class because her colleague was participating in Course 1, and the project directors thought it would be beneficial for them to have exposure to both courses so they could share their experiences. Leslie probably would have benefitted from participating in Course 1 as well because she had not experienced a curriculum like Core-Plus before she was a beginning teacher. Because the participants in the Course 1 sections of the Summer Institute were more

likely to be first-time implementers, the importance of trusting the curriculum was stressed in those sessions. At the beginning of the semester, it was apparent that Leslie was aware of her lack of trust of the curriculum. She stated:

I really do want to trust the curriculum and have them doing it and with the mathematical language like in the real world. But being realistic, I'm a first-year teacher. I want them to ask the questions that I've been asking. I just think that takes time with the students. With these students being freshmen and it's their first time coming in here. They're learning this process too. It's new for me. It's new for them. They have to learn how to talk and ask those questions. And right now I'm kind of probing and asking questions and eventually what I want them to do is ask the same kind of questions too. You can see them a little bit doing that a little in their groups. It's just trying to switch their minds and get them comfortable. A lot of them have to get used to working that way. And even retraining myself to not just give them the way to answer the question but to answer the question with another question and to learn certain and which way to ask the question to get them to thinking about the question (Interview on 9/24/2009).

Over the course of the year, Leslie internalized the need to trust the curriculum. Leslie attended the 2010 Summer Institute, and chose to enroll in the Course 1 class even though she taught Course 1 during the 2009-2010 school year. In a session during the 2010 Summer Institute, she shared with the other teachers that it was important to trust the curriculum and not to do too much. She shared, "When they say trust the book, they really mean trust the

book. Because I threw myself all kinds of ways...trying to pick up stuff that I didn't know...and bring back" (7/6/2010).

India had already experienced a significant adjustment period since it was her second year teaching with the curriculum. During the Summer Institute, she indicated that one of her goals was to improve in the area of assigning homework. The previous year she struggled with deciding which problems or exercises to assign for homework, especially when students had not completed an investigation in class. She said she felt she assigned too much homework the year before and was working to assign both more reasonable and more meaningful homework. Teachers new to the *Core-Plus* curriculum are likely used to assigning several exercises of practice for procedural fluency when teaching with a traditional curriculum. When assigning homework in the *Core-Plus* curriculum, teachers have to adjust to assigning what appears to be a smaller assignment for homework but only in the number of problems. The NCIM Summer Institute facilitators advised the teachers against having student complete investigations for homework because the investigations are designed to foster discourse among the students and they are typically not in an environment where they can talk with other students when completing homework at home. Instead, they suggested that teachers assign Check Your Understanding problems.

Another place where the teachers struggled was with providing closure to each day's discussion. Sometimes India used exit tickets on which she asked the students to complete an exercise or respond to a question like "What did you struggle with?" or "What do you suggest we could have done to make this experiment go more smoothly?" It was more rarely the case that the teachers closed the lesson by just announcing the homework or allowing the

announcements to be the signal the end of the discussion. Closure was particularly less likely to happen when the students had been working with their groups.

According to her content specialist observation reports, India's class<sup>8</sup> either ended with confusion about the day's work and homework assignment or upcoming assignments or projects. For three out of five observations that Leslie's content specialist observed the end of class, there was no closure. Her students worked until the bell rang or she just announced the homework assignment (9/16/09; 10/21/09; 2/11/10). The Summer Institute facilitators or content specialists emphasized the importance of providing some form of closure of the day's lesson and activities at the end of each class period. They suggested a number of ways for teachers to provide closure. Providing closure, though, seemed to be something the teachers needed to plan for, so that they would not get so involved in the class activities and forget to monitor the time.

It seemed that the teachers associated *Core-Plus* with more interactive or what the teachers called "exciting" activities than a traditional curriculum. Each of the teachers observed for this study seemed to get particularly excited if they were doing an activity with their students during an observation. If they were reviewing or doing a lesson that did not include an interactive hands-on activity, they shared before the visits that they were "not doing anything exciting," almost as a warning. As an example, before an observation, India eagerly shared that the students would be participating in an activity involving the electric slide. During this activity, which was not a part of any *Core-Plus* investigation, two students

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<sup>8</sup> Both Leslie and India had colleagues that also received visits from the content specialists. During the observation visits, the content specialists split their time amongst all teachers at the schools. This is why the content specialists were not always present for the end of Leslie's and India's classes.

painted the bottoms of their feet and then did the electric slide dance on a large sheet of poster paper. Afterwards they discussed whether the path their footprints created could be modeled using a linear function. India attempted to incorporate activities, pictures, or examples into her lessons. The electric slide activity, though, was difficult to follow and its purpose was unclear. In addition, it took a while for the set-up, and had not been planned out well because the students' paint wore off their feet quickly. She did set some of the challenges with the activity up to be worked on by the students. At the end of the activity, she asked them about things they would have changed for the experiment.

Research (Darling-Hammond & McLaughlin, 1995; Lloyd, 1999; Schoen & Hirsch, 2003b; Ziebarth, 2001) has shown that an adjustment period should be expected when beginning to work with reform-oriented curriculum materials. Interestingly, both teachers were often able to refer to behaviors or practices that should accompany teaching with *Core-Plus* according to the textbook and reform teaching practices. These ideas were either stressed at the Summer Institute or emphasized by their content specialists. Putting the ideas into action was another story for the teachers. This section has considered the teachers' struggles with adjusting to certain aspects of how the textbook suggests teachers present the material. Included in this section were the adjustments to the launch portion of the lesson and assigning homework. Another feature of the curriculum that requires adjustment is facilitating collaborative learning. The teachers' struggles with that aspect of the curriculum are presented in the next section.

## **Developing a Collaborative Classroom**

Another main difference between a traditional mathematics classroom and a *Core-Plus* classroom is its emphasis on active learning, collaborative learning, and group work. Students in *Core-Plus* classrooms spend a significant amount of time working together in groups. The curriculum materials were designed to support this type of learning with problem-based investigations that the students work on together. Learning to develop and support collaborative learning was a challenge for the teachers in this study. The Teacher's Guide explains that as teachers and students experience this type of learning, the issues encountered will subside (Hirsch et al., 2008).

The curriculum's Instructional Model explains that students work in pairs or small groups, while the teacher "circulates among students providing guidance and support, clarifying or asking questions, giving hints, providing encouragement, and drawing group members into the discussion to help groups collaborate more effectively" (Hirsch et al., 2008, p. xiv). The Teacher's Guide also provides guidelines to help teachers assist students develop productive collaborative group behavior. These included making sure every group member contributes to the group's work, understanding that every group member has the right to ask questions, that group members should help other group members, and that the groups should work together until every group member understands and can explain the group's work (p. T1B). Both teachers arranged the students' desks or tables in their classrooms such that three or four students worked together in a group. India's students also used group roles to share the responsibilities of the group's work. Each of the teachers, however, struggled in some sense to make the groups "work."

A challenge for Leslie was getting her groups to function with less dependency on her as the teacher. Her students sat in clusters and displayed the physical characteristics of “groups,” but worked more like a collection of individuals. During an observation early in the semester, she told a group that they needed to “work on working in a group,” because they did not work together to complete their assignment and they did not follow her instructions to turn in only one paper for the group. When students in Leslie’s class had questions, they consulted her before consulting their group members. She recognized that her students were dependent on her, and she expressed in a post-observation conference that she wanted the students to be less dependent on her during collaborative work.

Leslie wanted her students to be able to ask the types of questions she asked as they worked on their assignments. Leslie also commented that her students would often ask her if an answer was right. Leslie’s desires to increase her students’ independence were evident during observations when told them that she was not going to help them as much as she had in the past or that she was not going to “hold [their] hands” through the assignments. During her observations, though, when students asked questions, she did not direct the students to ask another group member.

Through the following quote, Leslie explained how she wanted her students during the lesson on finding equivalent expressions to ask each other or themselves the questions she would ask them and to not immediately ask her if their answers were correct. She stated:

I really want them to because I don’t necessarily tell them how to do a problem (table, graph algebraically) for them to know that there’s those options. And maybe on one or two for them to do it that way. What I find sometimes is they get an expression, I

notice their instinct is to ask whether it's right or not, so that's the biggest thing. You can tell me. How do you know? (Interview on 11/6/2009).

Another area in which the teachers struggled is with keeping the groups on task and helping the students use their time effectively. India had concerns about whether her students were using their time wisely in their groups. Her concerns prompted her to experiment with different group configurations during the study. She began the year with the students in groups of four. In addition to her concerns about ineffective use of time, she noticed that most of the time her students worked with the person next to them instead of the person across from them. Both of these observations influenced her decision to switch to student pairs in November. She made the following comment about the change:

[T]hey've been doing good in their pairs. When I listen to them, their conversation - it's really about the math. I heard some kids get off topic, but it seems that it's like it's not as bad I guess you could say as when they were in groups of four. It's like they're a little bit more focused on the job and the task (Interview on 12/1/2009).

These issues associated with collaborative learning affected how the students used their time when working in groups. Both teachers were concerned with time management and keeping on pace for the school year, but they lost some time when students worked in groups. During a post-observation conference, India asked to view a portion of the group videos after expressing her concern with their use of time. After I chose a clip and showed it to her, she stated that she enjoyed seeing "what the students were really saying in their groups and listening to their conversations." She was surprised to see how focused they were on their tasks, but also had an opportunity to observe how long it took them to accomplish an



assigned task. She realized that her students were less structured as she would have liked in group work. She also realized the students were spending valuable time on assigning group roles to each other. She stated:

I think it [the video clip] shows me that they could be a little more structured within the groups. Like their roles. Instead of them assigning the roles, maybe I need to go around and give them a role....Because I think that's what's taking up the majority of the time – them doing the actual thing (Interview on 10/13/2009).

Here, by “actual thing,” India was referring to the allowing the students to decide their roles during the time she allotted for them to work on their assigned task. After viewing video clips during our post-observation conference and realizing that her students were spending a significant amount of time assigning each other group roles, India decided to adjust how she assigned group roles in her classroom.

During the observations early in the semester, India asked her students which roles they were assigning to each other. Before they started working, the students had a discussed which student would act as the reader, for example. Since their problems were accompanied by text for students to read before they began working, the discussion would cut into their allotted time. The students then spent the first part of their allotted time to work on an assignment (which was often only five or six minutes, depending on the task) deciding who would assume which role. Her students seemed to be accustomed to a routine, but at the beginning of each new group activity each day, they discussed group role assignments. As a result, India ended up extending the time she allotted for the task because the groups were

unable to complete the task. She decided to assign the roles ahead of time to eliminate the need for so much discussion before the students even began to work.

India attempted to facilitate collaborative learning when her students worked in groups. Her students displayed signs of comfort working with each other in groups. They asked each other questions, sometimes emulating the types of questions India asked the whole class, and shared strategies amongst themselves without her prompting. India's content specialist also reported that her students (albeit in another class) seemed to be open to asking each other questions and answering each other (4/20/10). When India's students asked her a question, she often responded by asking whether they had consulted their other group members and would sometimes not answer a question until the student had consulted another student. As she walked around and monitored the groups while working, she asked her students if they were working together and reminded them that if they were working together then one student should not finish before the others. Even with her efforts though, her content specialist expressed concern about the engagement of all groups in her classes,

As the year progressed, Leslie felt that she reached some of her goals with managing her student groups. She made the following comment during a group discussion in the 2010 Summer Institute after attributing her growth to the reflection exercises she participated in during the post-observation conferences:

If you had come during the last two months of school, I remember being in groups and someone would ask a question and the person said beside them, "She's not gonna answer your question. ...[A]t the end, I mean I wasn't answering any of their

questions. That they would call me over to a group and I wouldn't help them unless they were completely at a dead end (7/6/2010).

Both teachers were aware of the challenges they faced with the students working collaboratively and made adjustments based on the recommendations from their content specialists and their experiences in the classroom. It can be questioned though, whether the adjustments were substantial. In India's case, on one hand, she made an adaptation in numbers, which might be very appropriate for her students and is a good sign as she was looking for the right behaviors. On the other hand, she practiced not helping her students until they needed her but there is less evidence that her reasoning is directly motivated to build understanding instead of just to do the practice. There is evidence of what it means to adapt her practice and what an observer needs to look for. Over time, they were able to make improvements facilitating the collaborative learning called for by the curriculum.

### **Weaknesses in Content Knowledge**

Teachers' implementation of curricula can be related to their content knowledge (Post et al., 2010). The evaluation reports (Confrey et al., 2008; 2009) showed how the teachers' weaknesses in content knowledge act as an obstacle to successful implementation of *Core-Plus* and fostering discourse while implementing *Core-Plus*. An assessment was given to the teachers at the beginning and end of the Summer Institute to gauge whether their knowledge of the mathematics in *Core-Plus* had improved over the course of the first week. Members of the research and evaluation created the assessment and the project directors reviewed and helped revise the assessment. Assessment items were similar to the material found in the *Core-Plus* textbooks. The teachers' scores are found in Table 1 along with the average scores

of the other NC-STEM partner schools and the entire group that attended the Summer Institute.

Table 1

*Teachers' Scores on 2009 NCIM Summer Institute Content Knowledge Assessments*

Teacher	Pre-Test	Post-Test
Leslie	42%	59%
India	48%	49%
Average NCIM (n=11)	49.18%	60.45%
Average All (n=59)	58.68%	68.46%

The teachers, overall, did not acknowledge their weaknesses in content knowledge as an obstacle, but an observer is able to see its impact on two components of classroom discourse: students are not provided accurate instruction or feedback and responses to student proposals lacked mathematical precision. Both of these forms of weaknesses in the teachers' practices affected their ability to facilitate the curriculum.

Leslie's fall semester courses were Course 1, which contain less challenging material than the higher courses. Hence, struggles with content were less apparent in her instruction than India's were. India taught Courses 2 and 3, which contained material that is more challenging. She admitted that she struggled with some of the material covered in the higher courses. India admitted that she experienced difficulty implementing two particular investigations; she mentioned proofs in Course 3 and solving quadratic formulas in Course 2.

She said that proofs were a struggle for her because she “did not like them” and struggled with them herself. Since India chose her semester long Course 2 class for this study, I did not have an opportunity to observe her teaching proofs. India’s content specialist recorded in her observation reports (8/5/09; 9/1/09) that she was in need of ongoing content support. After a visit, she described India’s content delivery as “inaccurate” and “unclear.” On the observation report for this visit, she wrote that India, “displayed a complete misunderstanding of the topics discussed, which created a chaotic class of students who were thoroughly confused. Specific areas of misunderstanding included types of angles (angles formed when two parallel lines are cut by a transversal) and logical thinking/steps to write a two-column proof’ (9/1/09).

A deeper look at the discourse between the students and India illuminates some of the gaps in her content knowledge. The following excerpt is included as an example when a stronger hold on the content knowledge would have made for a meaningful discussion with the students. During this classroom observation, India’s students were responding to a TATS that asked the students to examine a set of data and decide which function best modeled the data. One student suggested an exponential decay function and another student suggested an “indirect” function. The class spent seventeen minutes discussing which function would best fit the data, and the discussion was thwarted only because of a fire drill.

One student read the introduction to Unit 5 Nonlinear Functions and Equations aloud.

Another student read the introduction to the lesson:

Luge is a winter sports event in which competitors slide down an ice-covered course at speeds of up to 70 mph, lying on their backs on a small sled. Luge races are timed to the thousandth of a second, reflecting the narrow margin between victory and defeat. Along with the skill of the athletes, gravity is the major factor affecting the time of each run. Theory about the effects of gravity on falling objects (ignoring friction) predicts the following run times for a 1,000 meter run, straight downhill.

Vertical Drop (in meters)	Run Time (in seconds)
10	143
20	101
30	82
40	71
50	64
60	58
70	54
80	51
90	48
100	45

The following was the TATS:

Inspecting the (*vertical drop, run time*) data makes it clear that *run time* depends on *vertical drop* of the luge course.

- What kind of function would you expect to provide a mathematical model for the relationship of those variables?
- How would you go about finding a rule for such a function?
- How would you expect run times to change if, like most luge courses, the path downhill had a number of sharp, banked curves? (Hirsch et al., 2008, p. 326).

Here is an excerpt of the discussion:

India: So you can see the vertical drop. So if you're vertically dropping at 10, 20, 30, et cetera, you can predict your run time in seconds. Okay? So how long it's gonna take you to race ignoring friction or gravity. Okay? So, it's either pulling you down or resisting you. Okay.  
*[India reads the TATS aloud to the students. It is also important to note that India tells the students to ignore both friction and gravity. This statement, while it could have been an error, is inaccurate. They should indeed ignore*

*friction, as the problem reads, but not gravity. Her last comment, “So, it’s either pulling you down or resisting you” is also confusing.]*

India: *[She reads part a]* What kind of function? So, what type of function, meaning like linear, exponential, inverse, direct. What type of function would you expect to see?  
*[Above, India reminds the students of the types of functions they had reviewed previously instead of seeing what the students would come up with on their own.]*

Andy: Exponential.

India: Rashad, what do you think?

Rashad: I think it’s indirect.  
*[India writes both on the board.]*

India: Okay. Indirect. Anything else?

Rashad: Hold on which way is it going? Is it going down?

India: Look at the table.

Rashad: I know. But is it coming this way? Oh no – it must be going this way.

India: How many think it’s exponential?  
*[The students talk among themselves.]*

India: Exponential decay or growth?  
*[India asks Andy, and he responds.]*

Ryan: Decay.

India: Okay so I’ll put decay, so we can specify for Andy. Okay, so how many think exponential decay?  
*[She counts thirteen students who agreed with Andy.]*

India: So how many think it’s indirect or inverse?

India: Oh so now you change your mind, Rashad?  
*[India laughs.]*

India: So kind of wishy washy? Some of you? Five of you?  
*[Here, India listens to the students’ responses, and tries to get everyone involved by asking who agrees with both of the suggestions.]*

India: Okay. B) How would you go about finding a rule for such a function? So how would we go about writing a rule if we thought it was exponential decay?

Keith: You see where it says  $y$  equals  $m$  times  $x$ ?

India: Okay you’re writing a rule, they want to know how you would go about finding the rule. If they gave us that table of data, how could we use that table of data to find our rule?

Keith: So, it increases by 10 each time.

India: Okay.

Keith: So it would be  $y$  equals 10 times run time? Or something like that?

India: Huh?  
*[Keith repeats his response.]*

Keith: 10 times run time

India: 10 times your run time?  
Keith: Yeah.  
*[Here, it appears that Keith is only focusing on the difference in successive  $x$  terms.]*

India: Is that true? As  $x$  increases by 10, what happens to  $y$ ? Is there a constant increase in  $y$  or a decrease in  $y$ ?  
*[India asks Keith about the change in  $y$  values because he has been focused on the  $x$  values only.]*

Rashad: Hold on.  
Abram: No it's not 'cause it's ...  
*[Rashad interrupts.]*

Rashad: So it's not exponential!  
*[India has asked whether there is a constant increase or decrease in  $y$ , and Rashad rules out exponential because there is not a constant increase or decrease, but it is unclear whether the students and India are talking about the same thing.]*

India: So how am I to find a rule?  
D'Sean: You have to find a pattern right?  
*[India does not respond to this comment.]*

India: Is it linear?  
*[India can tell that the students are struggling here. The nature of her questions changes at this point. Rashad continues to advocate for indirect in the background.]*

Students: No.  
India: No. So, is it a constant anything? No. So how can we use our calculators...we've been doing it all along, to find a rule? Andy?  
*[India answers herself in these questions. The students want to use the table. She continues to refer to "constant," but has not cleared up the difference in the "constant" between the two functions, inverse and exponential. ]*

Andy: The chart?  
India: What chart? So how do I go about it after I enter them in my chart?  
Abram: You graph them.  
India: Andy? You said put them in there, but how do I go about finding my rule?  
*[The Teacher's Guide presented that students might suggest trial and error, algebraic reasoning, or using their calculator to fit a function to the curve.]*

Andy: I don't know.  
India: You don't know? Call on someone to help you out.  
*[Andy chooses Rashad.]*

Rashad: Well, I wasn't gonna help him out. I was going back to indirect. Would it be indirect because as your  $x$  increases, your  $y$  decreases? So would it be indirect or is it exponential like they said it was?

India: Can it be either or?



*[Rashad continues to argue for his suggestion of indirect. He is not convinced that an exponential decay function would best model the data.]*

Abram: Yes.

Rashad: No. Not exponential because we just checked that, and it's not going at a constant pattern.  
*[At this point, it is clear that Rashad's understanding of exponential may need to be addressed.]*

India: Whoa. Whoa. Whoa. Whoa.  
*[India recognizes that Rashad's understanding of exponential functions is unclear, but she does not explicitly ask what his understanding of exponential is until later.]*

Rashad: Or function or whatever you want to call it.  
*[Above, India's response suggests to Rashad that he has said something incorrect.]*

India: No. *[She repeats, "No" four times.]* Constant is linear.

Rashad: Alright, is it indirect though? That's what I want to know.  
*[I heard a student say, "She's not gonna tell you. You're going to figure it out."]*

Rashad: Because they think it's exponential, and I think it's indirect.

India: Can it be either one?

Abram: It could be.

Rashad: No. I don't think it's exponential.

India: Why not?

Rashad: Because it doesn't ...

India: What are you thinking exponential is?

Rashad: Alright, exponential is half, like halving.  
*[Above, it is evident that Rashad's experiences with exponential functions have included data with the pattern 1, 2, 4, 8, 16, 32, ...]*

India: Whoa – that's half-life.

Rashad: Half-life?

India: Yeah.

Rashad: You lost me. What's half-life?

India: What you just explained, that's half-life.  
*[Above, India does not explain what half-life is to the students. Rashad's reaction suggested that he had not heard the term before. She also does not explain that half-life is a form of exponential function.]*

Rashad: Okay then – can you explain what's exponential?

India: Exponential means that I either jump my numbers, so I'm exponentially growing. So, if I'm exponentially growing, that means I have something that looks like this or this or like that. I exponentially jump. Now this is growth. Now exponential decay means that I started somewhere here or I can be in the negatives or positives, and I'm coming down like that. That's exponential

decay. I come down at a sharp rate. Or with indirect. Remember you always started at zero.

*[The students sit while she draws graphs on the board. At this point, India's understanding of exponential is questionable and unclear.]*

Rashad: Well I'm lost, because I could've sworn exponential was like doubling when we went over it not last year, but this year.

India: Doubling?

Rashad: Well not doubling, but like increasing like 4, 8, 16, 32, I thought it was something like that. I don't remember exponential being that.

*[Rashad's example continues to be an example of an exponential function, but India does not use his example as the basis for the discussion. It is unclear whether she recognizes his example as an exponential function.]*

India: Say that again?

Rashad: I don't remember exponential being like that. So what's the definition of something being exponential?

India: You mean the rule or the explanation?

Rashad: If something be exponential whether it be decay or growth, what does that mean? That's what I want to know.

India: Okay exponential as in a situation or?

Rashad: Both.

India: Okay, so if I'm exponential growing, you can think of a cell like bacteria. So let's say you, you I don't know – got the cold. A cold infected you. Okay? It always starts off as one cell. Okay? If I look at it 5 hours later, I may have 64 cells.

*[India has chosen values arbitrarily, and her choice did not help to make her explanation clearer.]*

Rashad: And how is that? Because it started doubling off right?

India: Not necessarily.

Rashad: Alright then. Explain it. How did it get from zero to 64?

India: It didn't start at zero. It started at one.

Rashad: Alright then. How'd it get from one to 64 then?

India: Okay.

*[She erases the board writes 1 and 64.]*

India: So, if you start at one, and then five hours later you go to 64. Okay, so if you wanna break it up into times, you can break it up that way or you need some more times. So maybe eight hours from now, I have two hundred and something. So, seven hours later there was two hundred and something bacteria. Nine hours from now, I may have 1,000 bacteria.

*[India's use of time in this example is unclear and confusing. The values she provides are arbitrary (1, 64, two hundred and something, and 1,000) do not fit an exponential function where a whole number is raised to an exponent, which is the function Rashad has in mind.]*

Rashad: But I'm saying, how did it get from one to 64? Was there any repetitive action going on, like if you were going from two, and then four, and then eight?  
*[India could have used this time to explore Rashad's use of two more. She attempts to do so below.]*

India: It doesn't have to break off into two, but I'll use your two as an example.

Rashad: Alright.

India: Okay, so if you start with one, so this is one cell. So if this has 64, maybe it's breaking up like thirty minutes apart. Or maybe twenty.

Abram: 'Cause every minute, it's like four cells.

India: So, if I'm breaking off, you're saying I'm doing half. So I have two cells right? So within the next minute I have two different cells. These break off. Then I have four different cells.

Rashad: Okay. But do you see what I'm saying? See how it's like a constant pattern? And then each of those breaks off, and then what you had it breaks off. You see what I'm saying?

Abram: I see what he's saying. He's saying that if you got one...

Rashad: See, like you have one, and then it goes to two, and then four, and then eight.  
*[Rashad and Abram count together. Another student says, "That's linear." There is still confusion about the term "constant" when used to describe the pattern.]*

India: But Rashad, it doesn't have to break off at two. You're thinking about it like it's just one number, as two. So I have a double life. A cell doesn't have to break off by two. It can break off by five, six, eight.

Rashad: It also depends on the cell.

India: Tumor cells can start off like this. The next day, they can be the size of your fist. Different cells break off different ways.  
*[The conversation wanders into a discussion about half-life and objects that do not decay before Rashad asks another question.]*

Rashad: Alright, I'm just curious. Why would they put exponential? Why can't it just be decay or growth if it doesn't have a...  
*[India interrupts him before he finishes.]*

India: No. *[She repeats "No" five times.]* Andy said exponential, point blank period. That's why I asked him to specify was it growth or was it decay, and he said decay, and that's when everybody raised their hand once he said decay. And then you were saying indirect.  
*[She returns to the board.]*

India: If I have exponential decay, I can start at a negative number, okay?...With inverse or indirect, I'm always starting at zero. Now either case, could it be either one of these if you look at the graphs, what we have here? As I'm coming down my run time. It decreases. Does it really matter? Yes. But can it be either one of these functions if you look at what we're doing? Could it be indirect or exponential?

*[India's explanation above is confusing. She tells them that in exponential decay, she can "start at a negative number," but that with inverse functions, she "always starts at zero." It is unclear what exactly may start at zero and what cannot. It is also unclear and misleading because there is not zero value in the table, and students may think that they can just look at a table of data and see whether there is a zero and that will determine whether an inverse or exponential function best models the data. This happens later in the discussion.]*

Rashad: Well on this one, it's probably exponential because it's not starting at zero. It doesn't show your  $x$  starting at zero.

India: Does it have to?

Rashad: You said it had to...

India: *[India repeats, "No."]* Your graph will be at zero. Your table can I make it start at zero? *[She refers them to look at the table and not the graph that some of them were looking at.]*

India: So, if I look at the table, if you're thinking about the table and how I can represent this, either one of these will be fine. You're just thinking about. That's why it's called think about the Situation. There is really no conclusive answer now until we get to looking at different patterns.  
*[At this point only Rashad and India have been engaged in the exchange for a while. She and he continue until the bell rings for the fire drill.]*

India's content weaknesses are manifest in a few ways in this excerpt. The Teacher's Guide (Hirsch et al., 2008) stated that the teacher should expect that students would suggest an inverse or exponential rule as an appropriate model because of the nonlinear decreases in the table. It would have been interesting to see which types of functions the students would have suggested had India not listed examples early in the exchange. India asked twice at this point whether both rules could be possibilities, but Rashad continued to disagree with the possibility of an exponential rule. Notable to point out, is that the example India provides of the cold, is unlike the example in the TATS because the values she gives increase, while the run time data in the table decrease. Even though this is a TATS, during which the teacher should listen to students' suggestions and explanations instead of teaching, it is important

that accurate information come from the teacher and any inaccuracies be cleared up during or following the discussion.

In this particular case, India is allowing the students to debate whether an inverse or exponential function would best model the data. In exponential functions, the independent variable is the exponent. In addition, there is a constant ratio between successive output values. In an exponential decay function in particular, the ratio has a value less than 1, and the outputs decrease. As the value of the independent variable,  $x$ , increases, the value of the dependent variable decreases. This is the type of function Andy suggests they should use to model the data. On the other hand, with inverse variation a change in one variable results in a reciprocal change in the other. A form of inverse variation is  $y = k/x$ , where  $k$  is the constant number. India's comment

This exchange also provides another example of a TATS that lasted longer than it should have. This was a TATS, during which the students were to suggest a function rule and discuss how they would go about finding a rule. The focus of this investigation was reminding students about functions and introducing them to function notation.

This exchange is an example of when India delivers content inaccurately and unclearly. She does not explain that in exponential decay (or growth), the original amount decreases (or increases) by the same rate over a period of time. Her responses to Rashad do not clear up his misconceptions. Her responses also do not acknowledge his ideas that are correct about exponential functions. At no point does she explicitly tell him that the example he provided repeatedly was an example of an exponential function. The part of the exchange when India discussed the cold was an attempt to make the material relevant to the students,

but her explanation of the cell splitting was unclear. The choice of times she provided of five, seven, and nine hours later were also arbitrary and confusing. This episode shows how weaknesses in teachers' content knowledge can preclude them from responding to students accurately.

### **Incorporating Technology Tools**

Some teachers who participated in the Summer Institute were concerned with whether they would have the resources to implement *Core-Plus* at their schools. The facilitators during the Summer Institute modeled instruction using CPMP-Tools® and TI SmartView™ in their sessions. When the content specialists visited the teachers' classrooms, they indicated in their observation reports teachers' use of any technological tools during their classes. The graphing calculator was the only technology used in all of the content specialist site visits that they observed instruction<sup>9</sup>. The students also used graphing calculators during each of the informal and video-recorded observations I conducted.

Leslie had a document camera and a projector, but not a SMART Board or Promethean Board. According to her content specialist's observation reports, Leslie's students used their calculators to complete their assignments, and Leslie used the data projector to display a timer to help keep the students on task. She also used the data projector to display TI SmartView™ to review homework. Leslie's students also used the computers in her classroom to practice for the EOC tests.

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<sup>9</sup> Each content specialist performed ten site visits with each teacher. For India and Leslie, seven were actual class lessons. The content specialists met with the teacher during the other three for planning purposes.

India's classroom contained a document camera and a Promethean Board. India's observation reports (9/1/2009, 4/20/2010) show that even though she had a Promethean Board to use, she did not take advantage of all its capabilities. She used the Promethean Board to display a timer to help with time management and allowed students to use the calculator projected on the Promethean Board. India most often used the Promethean Board to display objectives, announcements, and assignments.

It is possible to teach with *Core-Plus* without the use of technology; however, the overview of the curriculum states:

Numeric, graphic, and programming capabilities such as those found on many graphing calculators are assumed and appropriately used throughout the curriculum... This use of technology permits the curriculum and instruction to emphasize multiple representations (verbal, numerical, graphical, and symbolic) and to focus on goals in which mathematical thinking and problem solving are central (Coxford et al., 2008, p. xi).

Leslie often shared with her content specialist that she wanted to learn how to incorporate more technology into her instruction, but needed help with how to do so. An example she provided was learning to connect the calculator to the computer and use the TI website. Because of this comment and others, a 2010 Summer Institute was designed with a greater emphasis on technology. If teachers have tools at their disposal, learning to integrate the technology available is a challenge to overcome. Teachers could take advantage of CPMP-Tools®, the software accompanying the textbook or other software packages to enhance their

instruction, but they may need more training and guidance to help incorporate the technology.

### **Managing Time - Planning and Pacing**

The evaluation report showed that teachers who participated in the 2009 Summer Institute anticipated challenges with planning (Confrey et al., 2008). These challenges included having insufficient time and resources to plan their lessons as well as planning for the entire school year. The findings from this study indicate that Leslie and India struggled with planning, pacing, and time management.

Leslie described the planning process as time-consuming. Her adjustment to the planning associated with teaching *Core-Plus* was complicated because it was her first year teaching. She knew that she also needed to consider her students' prior experiences and try to anticipate the rate at which the students would grasp the material. She declared:

With planning...I'm still getting used to everything. I think it's hard to know how long stuff is going to take and it's hard to know without doing the questions.... I can work it through, but I'm not in the students' mind, and I don't know what they've had and what they haven't had and so this year [I] make sure I take good notes for next year (Interview on 9/24/2009).

India described planning as stressful. At India's school, the principal had designated Monday mornings for lesson planning. She and another teacher at her school planned and collaborated with each other because they both taught Course 3. She said that the teachers who taught the same course at her school did not necessarily have the same lesson plans and pacing, but that they tried to cover the same topics. Teachers at her school also planned two



weeks in advance per her principal's requirement. India described this expectation as difficult. She explained:

You really want to focus on what you're doing this week, but instead you have to focus on what you're going to do the week after. When I was going week by week, it was easier for me because I could think about the activities I would do (Interview on 10/09/2009).

Both Leslie and India felt they needed to work through problems in the investigations before beginning the investigations with their students. Leslie explained that she planned by sitting down with the pacing guide and then planning broadly at first, then the lesson, then the investigation. She said she worked through the investigations to make sure she knew how to break down the questions in the investigations.

India's planning process was similar, as she described planning as especially difficult when working with investigations with which she was less familiar. She said:

You have to sit down and understand what it's asking and try to prepare for what they might struggle with and ask. And you want to scaffold, but not too much. It takes a lot more than to plan for that and make sure that everything is facilitated and going smoothly (Interview on 10/09/2009).

Both teachers were grateful for the assistance the content specialists provided with planning. The content specialists assisted with this hurdle by helping creating pacing guides and helping the teachers follow the guides. The teachers also found their planning meetings with their content specialists during their summer helpful.

Leslie and India, both mentioned time management as an area for improvement when teaching *Core-Plus*. Both content specialists also recorded time management as an obstacle for the teachers on their observations reports. Leslie felt like the hardest thing to work on was time management. She was concerned with “making it all work” with missing class for personal reasons and to take part in required professional development. She stated in a post-observation conference:

Time management is something I’ll have to constantly work on, but I think will come easier the next time I teach Course 1 because I know how long it takes and what I need and what I don’t need because that’s how I feel now. I don’t want to skip this problem or that problem or go over too fast (Interview on 11/5/2009).

The teachers struggled with both timing for individual lessons and pacing the course over the year or semester. All courses were semester-long at Leslie’s school, while India’s school offered both semester-long (for honors students) and year-long courses. The teachers were concerned with making sure the material students needed to know for EOC testing was covered. The semester-long courses were especially affected by timing issues.

Along with managing the 90 minutes spent in mathematics class each day, teachers also had to deal with the school calendar and the testing clock. When time and scheduling was a concern, the teachers omitted lessons according to the testing requirement of the course. The most dominant influence on what the teachers covered was the material assessed on the EOC testing. Both teachers adapted their implementation of both the content and the presentation of the lessons depending on their circumstances. India expressed in an interview:

I don't know if we'll be able to get to transformations with matrices because (she paused) they need the law of cosines more than they need transformations. So it was kinda like a pull and struggle. So it's just hard to skip some topics because you see it come up later and you're like darn. I didn't get to it in one of my classes last year. They got a brief introduction of it, and now they really needed it when they did congruency of triangles. I really think it should be taught in a year, but hey you know – you have to get the kids out of here because if they don't pass it you know... what can you do? (Interview on 10/09/2009).

While teachers may omit some sections to make time for other concepts, their students may be underprepared for topics in subsequent course and that teacher will have to re-teach or teach from the beginning concepts that would typically be considered prerequisite knowledge. India felt like skipping topics was especially difficult for her because she was familiar with the topics in the higher courses, and it was hard deciding to let some topics go because of time pressures and making sure the students were prepared for the next course. Some of the courses were taught for a semester (for honors students) and others for the entire year. The semester-long courses were especially affected by the timing issues.

The students were even concerned about what would end-of-course testing would assess. This concern about testing can be viewed as a factor influencing uneven implementation of the curriculum and how the teachers applied the ideas presented in the Summer Institute. Toward the end of the semester, Leslie found that she needed to “speed some stuff up.” Her content specialist reported when Leslie was behind her pacing guide, she cut down on parts of investigations to try to catch up. She also indicated that Leslie had a

“slow start” in August (11/13/2009). The first semester was an adjustment for Leslie, and she felt she would do better with managing her time the next semester. Leslie’s content specialist provided assistance determining what to include and what to omit as she found herself pressed for time toward the end of the year. In November, Leslie still had not started Unit 7, which the students needed before moving to Course 2. She and her content specialist discussed which units she should focus on to prepare her students for the Algebra 1 EOC test and which she could postpone until their school’s fourth course.<sup>10</sup>

Leslie approached the challenges with time management and pacing in various ways. In addition to omitting portions of the text, another way Leslie dealt with this particular time management concern was to issue a diagnostic test at the beginning of a unit to assess her students’ familiarity with the material so that she could make decisions about what to stress and possibly omit due to time pressures. Leslie, in another effort to save time, set aside the “experiments” from a unit for the students to conduct on one day instead of integrated throughout the unit as presented in the text. During an observation visit, the students worked through four or five activities in their groups, some were simulations from the *Core-Plus* book, and others were activities the teacher had found. The simulations are included in the textbook to facilitate the students’ learning and understanding of the concepts. Setting them aside to conduct out of the context possibly presented a disjointed experience for the students, as the curriculum emphasizes that the investigation approach is designed to help students “make sense of problem situations and construct important mathematical concepts

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<sup>10</sup> Leslie’s school used the fourth course as a “catch up” course. It was not the Course 4 of the curriculum.

and methods” (Hirsch et al., 2008, p. xiv). Instead of viewing the activities as aids in developing understanding, they were presented as fun, “add-on” activities.

Both Leslie’s decisions of giving the students a diagnostic assessment before beginning a unit and saving the experiment and simulation activities until the end of the unit were both examples of adaptations. The teachers made adaptations throughout their implementation of the curriculum - some of which might be tending towards detrimental adaptations and some of which might be reasonable in the context. The diagnostic assessment, for example, might make sense as an adaptation as it allowed her to assess the students’ familiarity with the upcoming content, while putting off the experiments until the unit’s end as “fun” is not an acceptable adjustment. Teachers will need to consider whether activities are critical for the development and understanding of concepts, and not just take them as fun or supplemental activities when using *Core-Plus*.

Leslie’s content specialist also recorded that her students’ lack of access to resources influenced how she was able to use class time. The majority of her students did not have access to a graphing calculator outside of school, so sometimes she had to provide time for her students to complete some of their homework assignments. There were certainly alternatives that the teachers could have suggested for students to use. These alternatives include on-line calculators and CPMPTools®, but there was the possibility and concern that her students would not have access to these tools either.

India’s content specialist reported that India struggled with fitting the content of the course in one semester. Even though some schools have adopted *Core-Plus* or another integrated mathematics sequence, their students still take the EOCs by subject area. One of

India's colleagues who taught the first course shared with me that her principal asked her not to cover the geometry topics with her semester-long students because most of the students knew the geometry material covered in Course 1 from middle school.<sup>11</sup> India said that she sometimes felt "rushed." During the times she felt rushed, she said she would end up telling the students what she felt they needed to know instead of asking them and having them discuss according to the *Core-Plus* principles and utilizing the investigations. She further explained that it was hard to allow students sufficient time to think and try to explain their thoughts when "you're rushed for time with the semester" (Interview on 10/09/2009). India might have felt rushed for a number of reasons. Time could have been spared by better managing discussions. India shared that her classes contained a range of ability levels. She felt that this made it difficult to determine how far she would get with the classes each day. She possessed these concerns especially in her semester-long course.

With timing and planning as an issue, it is helpful to look at the content the teachers covered during their fall semester, remembering that both classes were semester long courses. The TOC logs allowed for the calculation of Content Implementation Fidelity according to McNaught and colleagues (2008). The TOC logs were used to capture whether lessons from the curriculum were "taught, altered, substituted for, or skipped" (McNaught, Tarr, & Sears, 2010). The following three indices were computed: Opportunity to Learn (OTL) index; Extent of Textbook Implementation (ETI) index; and Textbook Content Taught (TCT) index. The OTL index tells the extent to which the content contained in the textbook

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<sup>11</sup> It was also the case that the students enrolled in the integrated sequence were exempt from taking the Geometry end-of-course test.

lessons was taught or not in terms of a percentage. The ETI index measures the extent to which the lessons that were taught from the textbook, vs. whether they were taught primarily from the textbook with supplements, or taught primarily from an alternative source, or not taught at all. An ETI index of 100 indicates that every lesson contained in the textbook was taught directly from the textbook. Finally, the TCT index considers only the content that students were provided OTL, and tells the extent to which that content was taught from the textbook, supplemented, or taught from alternative curricular materials. The three implementation indices for Leslie and India are included in Table 1.

Table 1

*Textbook Content Implementation Indices for Leslie and India from TOC Logs*

Fall 2009	OTL	ETI	TCT
Leslie (Course 1)	48.57	43.33	89.22
India (Course 2)	44.62	41.03	91.95

The OTL indices for both teachers show that both teachers did not teach over half the content in their respective courses. In Leslie’s Course 1, Units 4 (Vertex-Edge Graphs), 6 (Patterns in Shape), 7 (Quadratic Functions), and 8 (Patterns in Change) were completely not taught. In India’s Course 2, little of Units 4 (Regression and Correlation) and 5 (Nonlinear Functions and Equation) were taught, and none of Units 6 (Network Optimization), 7 (Trigonometric Methods) and 8 (Probability Distributions) were covered. The OTL indices are lower than the OTL indices calculated in the McNaught et al. (2010) study, in which they calculated an overall mean OTL index of 69.81 across 174 TOC records. They also found that teachers of

integrated courses had a lower mean OTL index (60.81, s.d. 19.98) than teachers of subject-specific courses (76.63, s.d. 17.02).

According to the breakdown of the ETI for India, 34% of the content was taught primarily from the textbook, 7% of the content was taught with some supplementation, and 59% of the content was not taught. For Leslie, 35% of the content was taught primarily from the textbook, 17% was taught with some supplementation, and 48% was not taught. McNaught et al. (2010) found that teachers of integrated courses taught slightly more content directly from the textbook than teachers of subject-specific courses, but did not teach more content than teachers of subject-specific courses. Both teachers in this study did not teach nearly half of the content in the textbook.

The TCT shows that of the remaining four units that Leslie did cover that semester, she taught the content primarily from the textbook. India also did not supplement the curriculum when teaching material from the textbook. McNaught et al. (2010) found that teachers of integrated courses had higher TCT indices than teachers of subject-specific courses. Research has suggested that a conceivable reason for variation in the implementation of the content is the requirements of high-stakes testing.

The teachers in this study omitted a significant portion of the text, and it is clear from their comments that their decisions about what to cover and what to omit were guided by what was tested at the end of the course. Perhaps the teachers needed to learn to be more efficient in time management. The teachers named both the Summer Institute and the assistance they received from their content specialists as beneficial while making planning decisions for teaching with *Core-Plus*. The potential lack of alignment between the end-of-



course testing and the curriculum they used resulted in a need to better understand the guidelines on what to omit from the curriculum when trying to prepare for the testing.

### **Promoting Mathematical Discourse**

The *Core-Plus* curriculum materials promote an increase in the discourse students have with the teacher and with each other. Promoting and facilitating classroom discourse was perhaps the greatest challenge for Leslie and India, and likely the case for any teacher new to *Core-Plus*. Striking the balance between encouraging student-talk while also guiding the direction of the conversations was a challenge when attempting to facilitate the discourse. Other issues within this area were increasing the amount of student-to-student talk and managing whole-class discussions. The second research question presents an extended discussion of the teachers' experiences attempting to promote classroom discourse.

From the visits in the teachers' classrooms, one could easily see that conversations could easily wander off-topic from the applied materials in classrooms using *Core-Plus* while attempting to manage the discussions because of the curriculum's connections to real-world situations. This wandering often occurred during the TATS. The TATS is intended to focus the students' attention to the problem situation guiding the investigation, but can easily lead to longer discussions that get off-course because the TATS typically presents a real-world situation. During a post-observation conference, Leslie shared that her class discussions could get off-topic. She recounted a time when her students entered into debate about taxes during a lesson. She considered the conversation "good conversation," but admitted that it took time away from the lesson.

India also drifted while teaching the lessons, but gave no indication that she was aware of it during the post-observation conferences. She acknowledged that her students might stray from the lesson, but did not indicate that she was aware of her influence. She made the following comment about the TATS as she laughed:

They start thinking way outside of the box, and I have to bring them back in the box.

They start thinking about just different situations where it's, you know, related to the math, but I think they're thinking about it in different forms (Interview on 10/09/2009).

The amount of student talk generated by a TATS can be exciting because of the real-world connections, but the conversations generated are not always meaningful or productive. If teachers are not careful, precious class time may be spent on conversations that take the students too far from the mathematics in the lesson. Straying too often during the introduction of the lesson can use class time that will be needed later in the semester.

The following example during which India introduces a lesson on quadratic functions is provided as an illustration of a class discussion that wandered. The Course 2 class was starting Lesson 1 in Unit 5, Quadratic Functions, Expressions, and Equations. A lesson objective was “Distinguish relationships between variables that are functions from those that are not” (Hirsch et al., 2008, p. T326). After her students completed a partner quiz, she projected pictures of objects that had parabolic shape (i.e., the McDonald's arches, a motorcyclist riding along a curved road, a segment of a rollercoaster, and an archway of a tunnel). After presenting the pictures, she asked the students if they had examples to share.

The students provided examples for six and a half minutes, before India engaged the class in a whole-class discussion during which the following exchange occurred:

India: So before we get to actually finding quadratic functions, we have to look and see if it is a function. Okay. So if I'm functional, I'm a function. So if you're functional, what does that mean to be functional?

Students: You work.  
*[Above, several students respond.]*

India: It works. Huh?

Students: Action.

India: Okay. You're in action. Anything else?

Students: Moving.

India: We already said you're moving.  
*[Abram comments about the previous discussion, "Hey, wouldn't somebody's ear be one?" He was referring to the discussion when the students were offering suggestions of objects in real-life that were parabolic in shape. A few of the students respond and laugh before India brings them back to the function discussion.]*

India: Alright so – is there anything else meaning functions? So I'm functioning. We said moving. Something that works.

Abram: Something that's that not non-functional.  
*[The students laugh.]*

India: Okay, so you just negated it. Okay so what is it to not be functional then?

Students: Steady. You're still. No movement. No action. No life.  
*[Above, several students provide these responses.]*

India: No movement. No action. Okay. Anything else?  
*[India pauses for a few seconds, but continues when no students respond.]*

India: Alright, so what's in the real world that's functional. What functions?

Students: Cars. Computers. Machines. iPods. People. The door outside.  
*[Above, several students provide these responses. India listens to the students' responses, but does not evaluate them.]*

India: Okay. So you're saying mainly technology. I hear people. Anything else that functions?

Student: Organisms

India: Alright, anything that doesn't function?  
*[Rashad quickly responds, "Food." Some students agree. Others disagree with "Yeah, it does. This is the first point in the discussion at which the students form camps and disagree with each other. The students talk loudly, and it is difficult to hear individual responses. Also, up until this point, India had asked questions of the students, and accepted their responses without evaluating them.]*

India: How doesn't it function? I mean what do you mean about food not being a function? What part of the food process?

Rashad: I'm talking about when it's sitting right there in the grocery store in a little box  
*[Abram adds, "or a carton."]*

India: So after you've harvested? So it's no longer functioning?

Rashad: Hold on, but not necessarily because doesn't it begin to rot away eventually? So you were about to tell me the wrong answer.

India: I wasn't about to tell you nothing. I asked you to explain what part of the food process you meant. So technically, it doesn't function after you cut it off and then before it starts to deteriorate. So, it's only in a certain interval, which we'll get to.

Rashad: So it's both in a way? It can be functional and non-functional?

India: Yeah. When is it functional?

Rashad: When is it functional? When it's in its growing stage and its decaying stage.

India: Okay. So then you have that stopping point, right? After you harvest it and then before it starts to decay. So during that time frame, I'm no longer functioning whether it be an apple an orange or whatever. It's no longer growing or getting bigger or anything like that. Okay. That's very good.  
*[Another student says aloud, Trees.]*

Rashad: Will we go over stuff like that? Like stuff that functions, then it doesn't, then it's functioning again?

India: Are you meaning separate parts of a graph? Like looking at the graph or looking at its stages?

Rashad: Probably the graph, because I already understand the stages. Like will we go over that?  
*[Above, the exchange occurs between India and only one student. D'Sean asks "What are we talking about?" Abram responds, "Man, I don't even know." India repeats, "Functioning and non-functioning."]*

India: Yeah.  
*[Another student responds, "Trees."]*

India: When does a tree not function?

Keith: Like after it's finished growing.

India: Noooo. A tree always grows.

Abram: No. What about when you chop it up, it's not functioning, but when it's growing it's functioning.  
*[The students talk about trees not moving and standing still.]*

India: What tree moves?  
*[Students begins to talk loudly until India calms them.]*

India: Hold on. *[India speaks slowly.]* A tree continues to grow until you take its trunk away, which if you look out here, those trees there keep growing and growing and growing. It'll never stop growing. Until you take it away. Like when you take it out of the ground. It'll keep growing.

Rashad: When does a tree die?

- India: When you cut it.  
*[There is student chatter. The students sounded excited, but their conversations were inaudible. Some students continue to chat among themselves as India explains further.]*
- India: When a tree grows, it starts like a seed, right? Just like those collard greens. They start like little seeds. They start to come up. Now a tree may reach its maximum height at a point like it'll never get any taller, but it may grow width wise. So depending on what type of tree like pine trees. Pine trees get very tall. They keep growing. He ones that have the acorns, you know? Those trees or pine cones. Okay? Now the ones with acorns, they get tall, but they're very wide as well. Okay. Or a pecan tree, or a plum tree or an apple tree. Now an apple tree, they have different functions. Like a fruit-bearing tree has a different function than just a tree alone.

The conversation continued an additional seven minutes, for a total of thirteen minutes total. A student expressed that he had never seen an apple tree, and India continued to talk about different types of trees and how tall and wide they would grow. The discussion then turned to the types of animals that eat the products of the trees. Some of the students were engaged in the discussion, but the conversation drifted too far from the topic. Although India began the discussion not evaluating the students' responses, it is noticeable that once the conversation changed gears, India no longer just listened to her students, but instead began to take an evaluative stance. The Summer Institute facilitators stressed that the TATS should not last this long. The content specialists did as well when they visited the teachers. They reiterated that the purpose of the TATS was to encourage the students to talk and share their initial thinking. The teacher is also able to assess student knowledge before beginning the investigation through the TATS, according to the curriculum materials (Hirsch et al., 2008). The NCIM staff encourages the teachers just to listen to the students' responses without evaluating their responses or providing any correct solutions.

India's attempts at promoting student discourse are evident through her questions. At the beginning of the discussion, she asked the students for the definition of "functional," the students responded, and she moved on to either the next question or student comment without evaluating comments. She encouraged them to think harder by asking for examples of things that did not function. Once the student responded, "food," the discussion shifted and India lost the gains she made about something changing or moving. During the discussion about food, India began to explain more and include her thoughts. The discussion about trees illustrated best that the discussion was no longer directed toward the lesson's goal.

According to the textbook, the first investigation of the unit would address the following three questions:

Which relationships between variables do mathematics call functions?  
What is the standard notation used to represent information about functions?  
What do the terms *domain* and *range* mean when referring to functions?

The textbook suggested that the investigation be introduced through a TATS about the winter sport luge (presented in an earlier section). This episode also portrays an attempt by India to adapt the curriculum, and suggests the possible disadvantages to supplementing the curriculum materials especially without the textbook as a guide.

Leslie and India both believed that using *Core-Plus* in their classrooms called for redefining the roles of the student and the teacher. They both used the term "facilitator" to describe what they felt they should be doing as teacher in the classroom. They also believed that the idea was to get students to talk more and explain their thinking and the way to do that

was through asking good questions. Leslie's struggles can be linked to the fact that she was a first-year teacher. She wrote on a reflection sheet during the Summer Institute that "being a first-year teacher and still learning the classroom and *Core-Plus*" would make it challenging to develop a discourse community in her classroom.

It was apparent from their comments and behaviors that both teachers wanted to develop a discourse community in their classrooms. The findings shared in this section and the next section show the efforts they made and challenges encountered when attempting to develop a discourse community in their classes. The second research question focused on how the teachers dealt with the challenges and the progress they made changing their instructional practices and developing a math-talk learning community.

**Research Question 2: How do teachers attempt to develop a math-talk learning community after participating in the 2009 NCIM Summer Institute?**

Although teachers are likely to encounter obstacles when implementing *Core-Plus*, even after participating in professional development, there is evidence that teachers can make progress in a semester. Both teachers perceived they benefitted from attending the 2009 Summer Institute, and an examination of the data collected throughout the study suggests that they both attempted to apply the ideas from the Summer Institute. Of the various ideas presented and modeled during the Summer Institute the teachers focused most on trying to improve their questioning behaviors and developing a math-talk learning community or a discourse environment in their classrooms.

As previously discussed, a focus of the 2009 Summer Institute was student discourse, with specific emphasis on creating and facilitating a math-talk learning community, a

community in which students and teacher engage in mathematical discourse (Hufferd-Ackles et al., 2004). Research has shown that creating a math-talk learning community is an intimidating task (Hufferd-Ackles et al., 2004). In building this environment, teachers must effectively enact a number of instructional practices. Watching teachers strive to implement “math talk” reveals ways in which such implementation encounters challenges and obstacles. These include effective engagement of students in mathematically substantive exchanges, keeping discussions on topic, and asking questions that require students to explain their thinking. In whole-class discussions, an observer would mainly see the teachers asking questions and students responding to the questions or students asking questions to the teachers and the teachers responding to the students’ questions. The teachers seemed concerned with their questioning practices in general, but needed to attend more to the relationship between the types of questions they asked and the kind of discourse that resulted.

The participants in the Summer Institute indicated that while they saw the benefit in incorporating the questioning techniques modeled during the Institute into their instruction, they anticipated challenges attempting to improve their questioning. As an exercise during the Summer Institute, the teachers reflected on their classes from the previous year and evaluated the extent to which they had facilitated a math-talk learning community. Since Leslie had not taught the prior year, she wrote that she anticipated that “being a first-year teacher and still learning the classroom and *Core-Plus*” would make it challenging to develop a discourse community in her classroom. India wrote that a challenge the previous year was making sure all students were participating. To assess the teachers’ development in creating a discourse community over the course of the semester, the teachers and I reviewed the Math-



Talk Learning Community framework during the post-observation conferences. During each conference, before viewing video clips of the teachers' instruction, I asked them to reflect on the framework and share their thoughts about each of the components (i.e., questioning, explaining mathematical thinking, source of mathematical ideas, and responsibility for learning). Sometimes the teachers rated their class according to the levels of the trajectory by stating a level at which they felt their classes were, and at other times they only discussed practices they were trying to improve. When reviewing the components of the framework, both teachers considered the Level 3 as the ultimate goal to reach in each of the components, and they often compared their classes to the description at Level 3.

Both teachers talked more about the first two components, questioning and explaining mathematical thinking, than the last two, source of mathematical ideas and responsibility for learning. A couple of explanations are possible. For one, a common instructional framework that presented attributes in a mathematics classroom guided the NC-STEM partner schools. The common instructional framework outlined six areas of focus for instruction, one of which was classroom talk. Another possible explanation is that the Summer Institute focused on teachers' questioning, and inherent in a focus on questioning, is attention to students' explaining because of their close association. The teachers' focus on these two components suggests something about their willingness to turn over control and possibly what they know about how to develop student responsibility for their own learning.

Accordingly, the teachers' experiences related to only the questioning and explaining components of the math-talk learning community framework are presented in this section. I viewed the video-recordings and analyzed them for evidence of the teachers' questioning and

students' explaining. I explain the growth that occurred in the questioning and explaining components of the Math-Talk Learning Community framework. I include excerpts of dialogue between the teachers and their students to help illustrate the questioning, explaining, and the growth in both areas that occurred during the semester.

### **Questioning**

Questioning is an important part of the math-talk learning community and mathematics reform teaching in general, because questioning of students helps the teacher learn what students know and how they think about the mathematics they are learning (Hufferd-Ackles et al., 2004). The Math-Talk Learning Community framework delineates the different levels within the questioning component by spelling out the transition from the teacher asking most or all of the questions in a mathematics discussion to sharing that role with his or her students. Within this component two shifts occur: one, from the teacher as sole questioner in the community and two, from questions focused on finding right answers to a focus on uncovering the mathematical thinking behind the answers given (Hufferd-Ackles, et al., 2004).

Both teachers were aware of a need to improve their questioning techniques. They also believed the goal was to get students to talk more and explain their thinking and the key to these behaviors was through asking good questions. Even though Leslie and India wanted to increase the amount their students talked and the quality of discourse in their classes, they had to learn to manage the discussions that occurred in their classrooms. The video-recordings of their instruction provided evidence that the teachers strived to ask questions. An observer in their classrooms on a typical day would likely see an energetic teacher asking

students a great number of questions and some students genuinely engaged in the lesson. With a closer look though, while there is what seems like a great deal of discussion, not everyone participates and while the teachers ask plenty of questions, the teachers' questions do not always elicit student thinking.

The Level 0 classroom in the Math-Talk Learning Community framework is the traditional mathematics classroom in which the teacher is the sole questioner and asks questions of students that typically require one word, brief responses. The questions at Level 0 are short and function to keep the students listening and following along. Like the teacher in Hufferd-Ackles et al.'s study (2004, p. 92), it was easy for Leslie to make the shift to Level 1 questioning because the *Core-Plus* curriculum materials prompt the teacher to begin asking questions of "How?" and "Why?" of students. Likewise, India's questioning was often at Level 1 or higher because she had taught using the curriculum the previous year.

At Level 1, the teacher is still the only questioner, but she begins to focus on student thinking and not just on their answers. Also at Level 1, students provide brief descriptions at the probing of their teacher. There is evidence of Leslie displaying Level 1 questioning when she asked students how they arrived at their answers. She also asked follow-up questions after students responded with an answer that could have been elaborated upon. The excerpt that follows is from a video-recorded observation in September. The discussion is from Course 1, Unit 3, Lesson 1 –Modeling Linear Relationships, p. 150. The excerpt<sup>12</sup> is illustrative of transition to Level 1 questioning in Leslie's classroom, but also contains

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<sup>12</sup> This excerpt was presented earlier when explaining how Leslie went beyond the scope of the TATS portion of the lesson.

examples of Level 0 questioning. It also illustrates that she made the transition within the first couple of months of the school year.

- Leslie: So we're talking about linear relationships. What does linear mean?  
Carlos: It goes in a straight line.  
Leslie: It goes in a straight line. So, what does that mean, that it goes in a straight line?  
*[Several students respond. Leslie's question of "What does that mean?" is an example of a move to Level 1 questioning.]*  
Leslie: That's what it looks like, right? Does it have to look necessarily like this, that way?  
*[She demonstrates by placing her arm in front of her to symbolize the graph of a linear equation. Several students respond, "No."]*  
Leslie: What else can it do?  
*[Several students respond.]*  
Leslie: Can it go, I mean, what if it goes this way? What's it doing?  
*[Leslie demonstrated by placing her other arm in front of her to symbolize the graph of a linear equation with a slope of the opposite sign. Students respond "Positive. Rising." Above, when several students responded and their answers were unclear, she continued assuming that they provided correct responses. Several students were engaged in the conversation, but it is unlikely that they all could hear each other. When she noticed that several students were responding, she could have called on individual students to explain. She could have also encouraged student-to-student discourse by asking a few individual students to compare or add too each other's responses.]*  
Leslie: It's rising. So what's positive?  
*[Students respond, "The slope." Here, Leslie directs the students to the term slope, which they had not introduced into the conversation yet, and which had not been introduced in the investigation.]*  
Leslie: The slope. So what's it doing if my slope is positive? What's it doing?  
*[Students respond, "It's increasing."]*  
Leslie: It's increasing. So, if. Does it always have to be increasing?  
Students: No.  
Leslie: No. What else can it do?  
Students: It can decrease.  
*[Above, Leslie's questions elicited short answers rather than explanations. Here, her questions are Level 0 questions.]*  
Leslie: It's gonna be a negative slope. So, it can be decreasing. So if we're looking at linear relationships, and I look at a graph, and I know it's linear, what do I know I'm going to see every time?  
Students: A straight line.

Leslie: A straight line. I know I'm gonna see a straight line.

It is also apparent in this excerpt that Leslie repeated almost every response the students provide. The students did not display any signs that this practice affected them; however, the repetition was noticeable, redundant, and unnecessary.

At Level 2, a shift occurs from the teacher as the sole questioner to the students as questioners as well. At this level, the teacher continues to ask probing questions and facilitates student-to-student talk by asking students to be prepared to ask questions about other students' work, for example. Students ask questions of one another's work on the board, but at the prompting of the teacher. Leslie, in her five video-recorded observations, asked most of the questions, and her students only asked questions of her to clarify or repeat something she had previously said. Leslie's students rarely asked one another questions about their work, and if so, it was at the prompting of the teacher. Leslie's video-recorded observations show that she remained between Levels 1 and 2 most of the time. Leslie acknowledged struggling with allowing for student discourse at times. When we reviewed the Math-Talk Learning Community framework, she rated her classroom a Level 2 in the questioning component and made the following comment:

I think the idea is to get to a 3. I think I am at a 2. I get them to talk, and I ask them questions. So it's more student to teacher. It's them telling me stuff... They work in groups and talk to each other but as far as asking questions to students, I'm still working on that (Interview on 9/24/2009).

At Level 3, the teacher expects the students to ask one another questions about their work, even though her questions still guide the discussion. Also at this level, the students talk to each other without being prompted by the teacher. Students ask questions, which require justification, and listen to responses. The teacher is often not physically at the board, and instead students may guide the discussions and initiate questions. Student-to-student discourse was difficult for teachers to facilitate in their classes. There was no evidence in the video-recordings of Leslie's class functioning at Level 3 in the questioning component. It was not clear that Leslie expected the students to ask questions of each other, because she asked most of the questions during her observations. Her students directed their responses towards her and she did not create opportunities for them to ask questions of each other. She said,

I don't think I allow enough time for discourse sometimes. Sometimes when working, they'll automatically raise their hand for me to come help them versus really talking it through and trying sometimes. So that's one thing I'm really working on because obviously in class there are a bunch of people who speak up, but then half the people who don't. So it's hard when they have to do it themselves (Interview on 11/5/2009).

Leslie's questions in the beginning of the semester required short responses, did not elicit student thinking, and were directed toward the correct solution, thus funneling the students' thinking toward the right answer. It was obvious that Leslie was aware of the questions she asked and the types of questions she asked. There were visible instances when Leslie made the decision not to tell too much or where she thought more about her questions before she asked them. It was indeed a work in progress. When it was clear that she was

attempting to focus on her questioning, she would stumble or stutter through some questions. Leslie's content specialist also noticed this, and wrote in an observation report, "I thought you did a good job with questions, but I noticed you paused several times I think to adjust what you were going to say. It is good to give yourself a second to think/compose before you speak/ask questions." At other times, it would seem like she was overly redundant with her questions.

Leslie also often asked follow-up questions of the students who provided the correct answers. At times, this resulted in a discussion with only two or three students in the class - the ones who answered and sometimes those students who answered the loudest. It is noticeable in the videos of Leslie's instruction that, there are students who are consistently involved in the discussions and there are others who appear less engaged. During one of the post-observation conferences, I asked Leslie about strategies she had for checking to see if all students were following. She said that she knew that was something she needed to work more on. In later video-recordings, she began to ask the students whether they agreed or disagreed with solutions and strategies that were presented. Although she asked the students whether they agreed or disagreed, she did not subsequently ask for explanations of their agreement or disagreement. This practice could possibly be ineffective though for timid students with incorrect answers because they may not be comfortable verbally expressing their disagreement with the rest of the class until that social norm is established.

Facilitating student-to-student discourse was a struggle for India also. During a post-observation conference while India reflected on her classroom and the Math-Talk Learning Community framework, she rated her classroom at between Levels 2 and 3 in the questioning

component. She said that the lack of student-to-student questions kept her from assigning a rating of Level 3. She said she had trouble getting her students to ask each other questions instead of directing all of their questions to her. Even though India acknowledged that facilitating student-to-student discourse was a struggle, she made efforts to encourage student talk. The following excerpt is from India's class, from Unit 5, Lesson 1, Investigation 1 (Hirsch et al., 2008, p. 328).

(1) Use information in the table and graph relating downhill run times to vertical drop of the luge course to answer the following questions. In each case, explain what the answer to the question tells about the luge run variables.

- a. How is the fact  $f(50) = 64$  shown on the graph?
- b. What value of  $y$  satisfies the equation  $y = f(40)$ ?
- c. What value of  $x$  satisfies the equation  $50 = f(x)$ ?
- d. What value of  $y$  satisfies the equation  $y = f(10)$ ?
- e. What value of  $x$  satisfies the equation  $45 = f(x)$ ?

*[Anabel reads part a.]*

- India: Okay so what do you think they're asking us to do in a? If I look at that rule, what do you think they're asking us to do Anabel?
- Anabel: Look at the graph.
- India: Look at the graph? And what am I gonna find?
- Anabel: Um – *[pauses for seconds]* – 'cause you go to 50
- India: 50 for what?
- Anabel: 50 on vertical drop
- India: Okay
- Anabel: And then go up for run time, it's 64. It shows that it's the equation for 50 meters.
- India: So if I have a vertical drop of 50 meters, then my run time should be expected to be how long?
- Mindy: I have a question. So all you have to do is look in box like thing?



India: Well she looked on her graph because that's what it was telling her to do or you can look on your table.  
*[Above, India could have used this opportunity to have Anabel explain to Mindy in an attempt to facilitate student-to-student discourse.]*

Mindy: And it's gonna be like that every time?

India: No sometimes, you're just given a rule, and you'll have to substitute. So find out when this is this. So they give it to you easy now basically. So b, - does everyone have a written down, or do I need to write the explanation down. Oh – if you have a vertical drop of 50 meters, then you have an expected run time of 64 seconds. I'll write it. Okay?  
*[Here, she could have facilitated student-to-student talk by asking another student to explain.]*

India: Laura, can you read that question?  
*[Laura reads.]*

India: So what do you think they're asking us to do there?

Laura: Wouldn't you like look at the graph and the f comma whatever thingy isn't that for meters for the vertical drop, so you'd go to 40, and then 71 seconds would be y.

India: How should we write that sentence?

Laura: I put  $y$  equals  $f$  of  $x$ , and I said  $y$  is 71 seconds.

India: So  $y$  would equal 71, so if you have a vertical drop of 40, what should your expected run time be?

Laura: 71 seconds.

India: Exactly.  
*[India continues writing on the board.]*

Rashad: How'd you get 71 seconds?

India: Laura, you want to explain?  
*[Above, India facilitates student-to-student talk through asking Laura to explain her work – Level 2 questioning.]*

D'Sean : Look on the graph, son.

Rashad: Oh alright. I see the table.

India: You can use the table. She used the graph. You used the table? Either one. they gave you both. Did it specify which one to use?

D'Sean: The table is easier.

Rashad: The table because...

India: Exactly. It's easier to use your table because they gave you the number there. But let's say they gave you *[India thinks]* what's a number not up there? 15? So let's say they gave you 15, what would you have to use your table or your graph?

Students: Your graph.  
*[India gives the students four minutes to work on parts c and d in their groups.]*

The exchange is continued in the next section when India's growth in the explaining mathematical thinking is examined. India's questioning is at Level 2 because she is not the only questioner in the class discussions. Her students were comfortable interrupting her to ask questions requiring justification from the person answering and asking each other questions about their answers and work. At Level 3, student-to-student talk is student initiated, the lack of these behaviors keep India's questioning techniques from being Level 3,

Based on the observations and the excerpts presented, it is easy to see that teachers increase their frequency of questioning, but that those questions may not always result in improvements in classroom discourse. Instead of asking questions for the sake of practicing a pedagogical technique, teachers will need to learn what types of questions, when to ask them, and to whom. Questions that do not elicit student thinking and reasoning, but instead simply the correct answers and procedures, are less likely to promote the classroom discourse described in the *Standards* and in the math-talk learning community framework.

Despite what I observed, teachers would comment that they felt like they did a "pretty good job," with questioning. Both teachers consistently rated their questioning at a Level 2 or higher during our post-observation conferences. Throughout the interviews, both teachers also acknowledged questioning as a behavior they would need to continue working at as they saw it as key in getting their students to talk more about mathematics, but they felt they were making progress. One of the struggles for both teachers was trying to find the balance between asking a question that "leads them [the students] too much and asking a question that's too broad." India explained that she felt that her attempts at asking broad questions did

not go well. As a result, she felt like she had to ask more specific questions that might seem too leading or giving away the answer.

Over time, Leslie recognized that although she was asking more questions of the students, her questions were not higher-order and did not elicit student thinking. During a session of the 2010 Summer Institute in which a video clip of Leslie's was the focus, Leslie made several comments displaying her growth in questioning. She continued to acknowledge that questioning was an area in which she needed to improve, but was able to recognize the challenges I observed during the fall semester. She made the following comment about her questioning and being the source of mathematical ideas during the discussion:

This is one of my big things that I'm working on. During class, they'll say the answers and all that stuff and I thought I was doing really good with questioning. But watching this [a video of her teaching during the Summer Institute], I honestly thought I was the mathematical source, because ...the questions I was asking weren't questions to get them thinking. It was very easy questions where they could easily come up with the answer and they say their error. Even though they were telling me the answer, I feel like the questions I asked, they basically gave the answer (7/6/2010).

Several reasons are plausible for why teachers struggle with questioning, albeit they are tentative. There is an association between asking appropriate questions and responding appropriately to students' questions in order to facilitate discourse and the content knowledge of teachers. In order for teachers to question students, they must be able to identify draw upon and extend pieces from students' explanations. The focus on the EOC testing,

undoubtedly affected the teachers' questioning habits. With teachers so focused on making sure they cover the material on the EOC, they are likely to focus on making sure the students "get it," even if that means telling them the answer. The frequency of "telling" might be related to the perceived importance of the material. Both of these stem from a deeper belief though that the students are unable to learn alone and that the curriculum materials are not sufficient for facilitating their learning.

### **Explaining Mathematical Thinking**

The second component of the Math-Talk Learning Community framework is explaining mathematical thinking. Hufferd-Ackles and colleagues (2004) acknowledge that this component is closely connected with the questioning component. With this component, however, the focus is "exclusively on the process of explaining," and the idea is to shift to where students increasingly explain and articulate their math ideas (p. 96). In this section though, some commentary about the teachers' questioning will be included.

As stated previously, the students in both teachers' classes had to adjust to the expectation of explaining their thinking. Both teachers felt they made efforts to have their students explain their thinking. Leslie, for example, said that she made sure her students would always have to explain how they came up with their answers on quizzes and homework assignments. She also explained that she used "gallery walks" to provide students with opportunities to explain their thinking.

At Level 0 in this component, the students give answers to the teacher's questions in one to a few words. Almost all of the talk in the classroom is between the teacher and the student and consists of primarily short interchanges (Hufferd-Ackles et al., 2004). The

teacher's questions solicit short responses from the students that are typically answer-focused. At Level 0, the teacher may not wait for students to answer or even give the answer herself.

At Level 1, the teacher begins to probe students and their explanations become fuller. Making the transition to having the students provide fuller explanations requires patience on the part of the teacher and may result in longer pauses after questions have been asked (Tobin, 1986; Knuth & Peressini, 2001). Allowing students a suitable amount of time to answer the question posed by the teacher is an issue connected to explaining mathematical thinking. While Leslie asked questions of her students, her wait time was sometimes low for students to respond to her questions, and she either restated the questions or answered the questions herself when the students did not answer immediately. She appeared uncomfortable with the long pauses after her questions.

Also at Level 1 in the explaining component, the teacher begins to probe student thinking, but she may fill in some explanations herself. The students provide information about their thinking, but only when probed by the teacher (Hufferd-Ackles et al., 2004). The excerpt is from the first video-recorded observation, which occurred in late September 2009. Level 0 explanations are apparent in the excerpt that follows and shows that the students' explanations are geared towards finding the correct answer. This is facilitated through the questions Leslie asked. Examples of Level 1 explaining are also evident in this excerpt. In this conversation, Leslie introduced Lesson 1 in Unit 3 from Course 1, Modeling Linear Relationships after a student had just finished reading the introduction to the lesson.

Leslie:           So  $y = a + bx$ . Have y'all seen that before? Does that look familiar?

Students: Yes. *[Several students respond, yes.]*

Leslie: Yes. What does it...look like? Or it might have been written a little bit different how you learned it. How did you probably learn it before?  
*[Carlos responds  $y = mx + b$ .]*

Leslie:  $y = mx + b$ . Does it make a difference if I use  $a + bx$ ?

Carlos: No

Leslie: No. What does my  $a$  tell me?

Carlos:  $y$ - intercept.

Leslie: My...

Carlos: Oh. The  $a$ ? Yeah.  $y$ -intercept.

Leslie: Yeah. The  $a$ .

Carlos: Yeah.  $y$ -intercept.

Leslie: My  $y$ -intercept. So if I know my  $a$  in an equation is 30, what is that gonna look like on my graph? *[She waits 4 seconds, and no one responds.]* I might need to word that a little bit differently. If I have like 30 plus four  $x$ , where what [sic] am I gonna do with that 30? *[Leslie shifts to the procedural here.]*  
*[Students respond. One boy says that you plot (0,30), and then go "up four and over one."]*

Leslie: *[Leslie responds to him.]* Yeah. Oh you got real in detail! But the  $y$ -axis that's gonna be 40. What would be my coordinate there? Could you give me the coordinate if I know my  $y$ -intercept is 40?  
*[She switches to a  $y$ -intercept of 40 inadvertently. She realized it in the post-observation conference.]*

Carlos: Zero. Forty.

Leslie: Zero. Forty. Zero. Forty. Why is it zero?

Carlos: 'Cause it doesn't touch the  $x$ .

Leslie: 'Cause it's not going across any on your  $x$  is zero, so your  $y$ -intercept is where that's gonna cross. What's my  $b$  in this problem?  
*[Here – she's asking the students, but ends up giving the answer in the end. The students do not explain why the additive term would correspond to the intercept. The students provide short answers to Leslie's questions instead of explanations.]*

Carlos: The slope.

Leslie: The slope. What does the slope tell me?

Student: Rise over run.

Leslie: Rise over run. So, what is my rise over my run?

Student: How much you go up. How much you go over.

Leslie: How much I go up. How much I go over. Do I always have to go up and over?

Students: No.  
*[Here she asks the students if there was an alternative to positive over positive, but then provides the answer. She could have asked the students for other possibilities.]*

Leslie: No. Yeah, I could go down and over the other way. I mean you're just gonna go the way it tells you to. But what does that rise over my run tell me?

Mia: How much it's changing each time.

Leslie: How much it's changing each time. It gives me... I mean you're right, changing, if I say um – with the problems we were doing yesterday and I knew the unit price of those cans was like three cents an ounce, what does that tell me as I add ounces?  
*[Here Leslie is pushing for meaning and trying to get the students to connect to their previous lessons. She is still doing the majority of the work. The language is also unclear. Some students might not understand what "it" is.]*

Students: It's increasing.

Leslie: It's increasing. Does it increase by a specific amount?  
*[Here, she leads the students. She could have asked "How does it increase?" which would have been Level 1 questioning, the counterpart of Level 1 explaining.]*

Students: Yes.

Leslie: Yeah. How much does it increase by?

Kurt: By three cents.

Leslie: It increases by three cents every time, so if I know how much it's increasing or...  
*[Here, Leslie fills in explanations instead of probing students more, which illustrates Level 1 explaining.]*

Students: Decreasing

Leslie: Decreasing, it's gonna give me – in a linear is it gonna go at a constant rate?

Students: Yeah.

Leslie: It's always gonna go up every time I add something to my  $x$ 's it's gonna do that same thing to my  $y$ .

This next excerpt illustrates more Level 1 explaining. This excerpt is from a conversation with one of the groups after the gallery walk exercise. Leslie considered the gallery walk exercise an opportunity where the students would be explaining their mathematical thinking. During a gallery walk, the teacher assigns student groups to write the answers to a problem (with each group working on a different problem) on a sheet of paper (often a large post-it note or sheet of chart paper) and post them around the room. As the groups complete their problems, they walk around to the others as one would in an art

museum and check their answers. Leslie also instructed her students to carry small post-it notes with them and provide feedback on any problems or answers they questioned. In this particular gallery walk, Leslie’s students had completed six problems from an investigation on Getting Credit, also from Course 1’s Unit 3, Lesson 1 – Modeling Linear Relationships. After each group visited each poster, the class reassembled and each group presented their work to the entire class.

There was evidence of Leslie encouraging students to explain their thinking during the gallery walk exercise. After she explained the directions for the gallery walk, she floated around to each of the groups and asked the students questions like, “What do y’all think about it?” and “Do you agree with every part?” She continued this line of questioning during the groups’ presentations before the class. Still, the presentations were completely teacher-driven, as Leslie was the only one to ask questions and the students’ responses were always directed at her. The following discussion between Leslie and the students during a gallery walk exercise is illustrative. The group of students were solving the following problem. They solved parts a through e, but only a and b are included in this example.

**Selling Credit Cards** Companies that offer credit cards pay the people who collect applications for those cards and the people who contact current cardholders to sell them additional financial services. (1) For collecting credit card applications, Barry’s daily pay  $B$  is related to the number of applications he collects  $n$  by the rule  $B = 20 + 5n$ .

- (a) Use the function rule to complete this table of sample  $(n, B)$  values.

<b>Number of Applications</b>	0	1	2	3	4	5	10	20	50
<b>Daily Pay (in dollars)</b>									

- (b) Compare the pattern on change shown in your table with that shown in the graph on the preceding page.



Mia: Okay, well our problem was selling credit cards. *[Jamal reads the problem.]*  
 Okay so for our table for like zero, if you had zero applications, you're already starting at start at twenty. Then every single time it went up by five.

Leslie: Went up by five. So when my number of applications is ten, how much are they gonna get paid?

Mia: 70 dollars.

Leslie: What about 20?

Mia: You get 120.

Leslie: And 50?

Mia and Jamal: 270.

Leslie: 270. So I think we all agree because nobody had a note on any of that *[in reference to the post-it notes the students placed on the sheets during the gallery walk when they had a question or did not agree with an answer]*, did they? Does everybody agree?  
*["Does everybody agree" was a question Leslie regularly asked. A few students responded "yes," while others sat quietly. This seemed to be a tactic for assessing students' learning that did not work well, because if students did have different answers, they did not speak up and say that they disagreed.]*

Marisol: For b. It says *[Student reads part b]*. And um, we said, "It starts off the same, but once the table skips from five to ten, ten to twenty, and then twenty to fifty, it'll look different, because the slope increases on the graph."  
*[This was a missed opportunity to explore the students' thinking. Instead Leslie continued with questioning geared towards getting students to the right answer.]*

Leslie: Well, could I use this information from the table and make a graph from it?

Students: Yes.

Leslie: Yes. What would I do to do that?

Carlos: Plot the points.

Leslie: Yeah. Plot the points. How does...in this table, and this is something for all of you to look at and ask. I'm not just grilling the group up here. Look at the table all of you should have in your answers. How does it... um...What's happening to your daily pay?  
*[Above, examples of Leslie focusing on the student thinking. At this point students in other groups begin to answer Leslie's questions.]*

Students: It increases.

Leslie: It increases. How does it increase?

Kurt: By five dollars for each application

Leslie: By five for each application. If I have one application, and I gonna get 5 dollars that day? Am I gonna get five dollars that day if I get I application?  
*[But still here, Leslie continues to do most of the work instead of trying to get the students to do more of the explaining.]*

Students: No.

Leslie: No. Why?  
*[Leslie does not just accept the answer, “No.” She follows up with “Why?”]*

Kurt: No. You’re gonna make twenty-five.

Leslie: I’m gonna make twenty-five, ‘cause why?

Kurt: ‘Cause you have a twenty dollars base salary.

Leslie: ‘Cause I already have twenty dollars for even having no applications, so if I have one I get twenty-five dollars. So if you see, what’s like the pattern if so have you, in the table? What’s happening?  
*[Again, she takes the students’ explanations and makes them fuller instead of encouraging the students to do so.]*

Jesse: As the number of applications increases, your daily pay increases by five.

Leslie: Exactly. Now flip back and look at page 151. You already have the table, I mean the graph in your book. You didn’t have to do it. What’s happening in that graph?

Mia: It has an increasing slope.

Leslie: It has an increasing slope. How does it increase?  
*[Mia responds, “By ten.” Kurt says, “Steadily.” And another student said, “At a constant rate.” All three respond at the same time.]*

Leslie: Huh?  
*[Students repeat their answers.]*

Leslie: Steadily. Can you tell me that constant rate?

Kurt: Uh – ten over two.

Leslie: Ten over two, which is?

Kurt: Five over one.

Leslie: The same thing as five, so is... What can you tell me about the table and the graph? ‘Cause we just said, y’all just said the table increases by five and you said in the graph it goes up ten dollars for every two applications, so per application it goes up by five, so what does that tell? *[Leslie tries to catch herself from telling the answers.]*

Mia: They’re gonna be the same.

Leslie: They’re gonna be the same. If I plot those points, what’s my graph gonna look like?

Kurt: A straight line.

Leslie: A straight line but *[Leslie pauses]* what specific kind of straight line?

Kurt: A diagonal straight line.

Leslie: A diagonal straight line? *[The students laugh.]*

Carlos: Positive slope.

Jesse: An increasing straight line.

Leslie: Increasing. How does it increase?

Students: By five.

Leslie: By five. Is it not gonna be that same line on page 151? If I plot those points, is it not gonna give me the same graph as on page 151?

*[The students do not answer the question as Leslie expected, so she ends up telling them what she wanted them to say, but in the form of a question.]*

Students: Yes.

Leslie: Yeah. It's gonna end up being the same thing.

It is at Level 2, that the students begin to stake a position and explain their steps with fuller descriptions. It was clear from the later observations that Leslie made concerted efforts to not tell the answers. She sometimes stopped herself from telling the students something, and then switched to asking a question that would lead to what the intended response. Leslie said she had also made attempts at getting students to do more explaining through working problems out incorrectly on the board and having the students find the mistakes. During an observation, she had solved multi-step equations on the board with one or more common errors. The students worked with their groups to determine whether her solutions were correct, and they all reviewed their thoughts as a class.

The following excerpt from November does demonstrate the beginning of a transition to Level 2 explaining. In this excerpt, Leslie began the class by instructing the students to take out their homework. The class was Course 1, Unit 3, Investigation 2, The Same, Yet Different in which they needed to determine whether pairs of expressions were equivalent. Part b of number three asked the students to determine whether the two expressions,  $3(x-2)$  and  $6-3x$ , were equivalent. If the pair was equivalent, they needed to explain their justification, and if the pair was not, they needed to show that the pair was not equivalent. One of the strategies for determining equivalency of pairs of expressions was choosing and substituting a value and then checking the solutions. Most students used this method. They had reviewed that there were three ways to check - plugging in a number, creating a table, or

graphing the two expressions. Leslie asked whether the two expressions were equivalent and some students responded “yes,” while others responded, “no.”

- Leslie: In b, do y'all think b is equivalent?  
*[Some students say “yes,” and some students say “no.”]*
- Leslie: I heard no, and I heard yes's.
- Mia: Well let's find out.
- Leslie: Let's find out. I like. Say it out loud, Mia!
- Mia: Let's find out!
- Leslie: Y'all find out right now. You've got three ways you can do this. Tell me whether b is equivalent or not.  
*[Students go back and forth with “yes” or “no, it's not.” Carlos says, “Look at it.” Some students laugh.]*
- Students: It is equivalent. No it isn't. I don't think it is. *[The students go back and forth.]*
- Leslie: We have yes and we have no's.  
*[The students continue saying their answers loudly.]*
- Leslie: Well let's do – Hold on. Shhhh. Let's hear what Mia has to say.
- Mia: Instead of  $x$ , I put two, and I distributed, so you get six minus six equals zero. And then you multiply three times two.
- Leslie: Hold on. Give me the two expressions and then talk me through what you're doing.  
*[Leslie writes the two expressions on the board.]*
- Leslie: So Mia what did you do?
- Mia: Instead of the  $x$ , I put a two.
- Leslie: So two minus two.  
*[Leslie substitutes the two in and performs the operation in parentheses, but Mia did not proceed that way.]*
- Mia: Four.
- Another student: No zero.
- Mia: Oh zero, my bad.  
*[Students repeat “zero.”]*
- Leslie: Well hold...
- Mia: I did three times two, and then three times two.  
*[Leslie demonstrates on the board.]*
- Mia: Yeah.
- Leslie: You can, remember if you plug a number in here. Remember your order of operations. What can you do first? Even though it doesn't, you can do it either way.
- Mia: Oh. Never mind. 'Cause I...

Leslie: We can do it both ways. So you said three times two minus three times two which is what?

Students: Zero

Leslie: Six minus six. Now if I put two in here you can go ahead and do what's in your parentheses. What's two minus two?

Students: Zero.

Leslie: What's three times zero?

Students: Zero.

Leslie: So now I need to plug two in here and see if it's equivalent. And three times two is six. And six minus six is zero.

Jenny: *[Jenny jumps in.]* But two is the intersect. If you plug in a different number...

Julie: If you plug in one, it's gonna be three and negative three.

Marisol: And if you solve it algebraically *[she tries to say]*, you get three  $x$  subtract... *[Leslie jumps in here without letting Marisol finish.]*

Leslie: I heard somebody say... What is two in this problem?

Jenny: The intersect of the two lines.

Leslie: The intersection of the two lines, so that one point is what? *[One student says softly, "equivalent lines." Leslie waits three seconds.]*

Leslie: Like what is that one point saying?

Julie: It's where they cross.

Leslie: It's where they cross, so it's where what?

Julie: They're both equal to that number.

Leslie: Where what would be equal? Like...

Julie: They're equal if you plug in that number.

Leslie: They're equal if I plug in that number because it, when  $x$  is what?

Mia: When  $x$  is zero,  $y$  is the same no matter...

Leslie: But what did we just say the number is when they intersect?

Students: Two.

Leslie: So when  $x$  is two, what's gonna be... They intersect you're right, but what is that saying? *[It doesn't appear that the students understand exactly what she's asking. A couple of seconds pass.]*

Leslie: When they intersect, if you think back to the problems, remember how we set problems up with the systems of linear equations? What's that saying? *[The students still appear to be struggling.]*

Leslie: Not that they're not equal, but that they're only equal when...

Students: When  $x$  is two.

Leslie: When  $x$  is two, that's the only time they're gonna be equal. Plug one into both of those equations or another number. *[The students talk among themselves.]*

Leslie: If you plug any other number in, will you get something that's equal? *[The students respond with a choral no. Leslie goes back to the board and erases the two.]*

Leslie: So what does this tell you you should do? Yes Marisol?

Marisol: I made a mistake, and I saw my mistake. Because I solved it the algebraically way, and I multiplied three times  $x$  and got three  $x$  minus six. And I thought they were equivalent, right because they had the same numbers, but I saw that the second one is a positive six and in this one it's a negative six.

Leslie: Yeah. Are  $3x$  minus six and six minus three  $x$  the same thing?  
*[Some students respond, "no." Some respond, "yes."]*

Leslie: No. No. No. How would I know if they're the same thing?

Raul: Check it on a table.

Leslie: Check it on a table. Check it on a graph. I could put a number in. So this – should I 100 percent maybe rely on just plugging a number in?

Carlos: No. *[He responds loudly.]*

Leslie: Maybe what should I do?

Carlos: At least try two different ways. *[Another student responded, solve it both ways.]*

Leslie: I should try at least try another way to make sure that I'm not picking the one point where maybe they are equal to each other? So what do you find if you put those in  $y$  equals? Are they equivalent?

Marisol: For them to be equivalent it should be negative three  $x$  plus six. Negative three  $x$  plus six would be the equivalent one to that.

Leslie: You need to make sure you're doing many ways. Any questions on that?

Jenny: So it's not equivalent?

Leslie: No.

Jenny: Woo! I got it right!

In this excerpt, the students staked their positions without significant probing from the teacher. They took ownership of their approaches and defended them until they resolved the issues as a class. In Level 3 of the explaining mathematical thinking component of the framework, important information comes from both the students and the teacher (Hufferd-Ackles et al., 2004). It came up in the post-observation conference after this observation that Leslie's earlier classes did not encounter this debate. She said that none of the students selected the point of intersection to substitute into the two expressions to determine whether they were equivalent. She also admitted that she had not anticipated that occurrence and had to revisit the concept the next day in her other two class periods.

During Leslie's observations, she tended to only ask questions of the students who provided correct answers, so all students did not have the same opportunity to offer their explanations, especially if they were uncomfortable speaking up in class without being asked by the teacher. In several of her video-recorded observations, select students (often the same students) responded to her questions without prompting. Others responded when she asked questions more than once and some still would not speak up. She often asked, "How did you get that?" when a student gave a response, but only of the students who provided a correct response. Because Leslie often asked questions until she heard the correct answer, it might appear to an observer that she was having a conversation with only two or three students in the class. She recognized during the video viewing that there were some students she never checked on to see if they were understanding or passively participating.

The trajectory, though, includes elicitation of student thinking, strategies, or explanations. At Level 3, students describe more complete strategies, defend and justify their answers, all with little or no prompting from the teacher. Both teachers set this level as their goal. There was little evidence in Leslie's video-recordings of her students confidently and thoroughly justifying and defending their mathematical ideas without her probing.

Like Leslie, India also felt like she encouraged students' explanations of their mathematical thinking. She described her efforts this way: "I always ask 'why.' They hate it, but I think a lot of them still throw out their answer, and kind of hoping – is she gonna ask me why? I think most of them have prepared themselves to like, they really won't respond unless they can give a good explanation. Or if they think they have the answer they'll say it but they're looking for a response from their classmates like 'how did you get that?'"

The following excerpts are presented to illustrate the student explanations that occurred in India's class. India does not accept the short answers her students provided. Instead, she asked follow-up questions requiring them to explain their answers further. The following excerpt is the continuation of an exchange presented earlier from Unit 5 Nonlinear Functions and Equations (Hirsch et al., 2008, p. 328):

- (1) Use information in the table and graph relating downhill run times to vertical drop of the luge course to answer the following questions. In each case, explain what the answer to the question tells about the luge run variables.
- How is the fact  $f(50) = 64$  shown on the graph?
  - What value of  $y$  satisfies the equation  $y = f(40)$ ?
  - What value of  $x$  satisfies the equation  $50 = f(x)$ ?
  - What value of  $y$  satisfies the equation  $y = f(10)$ ?
  - What value of  $x$  satisfies the equation  $45 = f(x)$ ?

India: Cain, what did you get for 1c? *[Cain was a quiet student, who did not speak up in whole class discussions unless India asked him a question.]*

Cain: 80.

India: 80? How'd you get 80?

Cain: I looked on the table.

India: You looked on the table? What did you look for on the table?

*[She doesn't accept the short answers – attempts at getting the students to explain. At Level 1, students give information about their math thinking as it is probed by the teacher, and they provide brief descriptions of their thinking. Cain prepares to explain, but India interjects.]*

India: Like did you look for the  $x$ 's or the  $y$ 's?

Cain: I looked at 51, and I went to the left and it had 80.

India: Okay so you used the table or the graph because you just said both?

Cain: The table.

India: So you went to your run time and found out when it was 51 in the table and then looked at your vertical drop and it was 80 meters? Questions for Cain?

You all got that? You sure? Alright Jaxon. What did you get for 1d?  
*[Above, India attempts again to facilitate student-to-student talk by asking students to explain their work.]*

Jaxon: We got... We got 143.

India: How'd you get that?



*[Each time the students provide an answer, India asks “How?” or “Why?” The students do not describe their strategies without prompting from the teacher, which would be illustrative of Level 3 explaining.]*

- Jaxon: We looked at the table.  
India: Looked at the table and did?  
Jaxon: We looked for ten.  
India: Looked for ten where?  
Jaxon: On the vertical drop.  
India: On the vertical drop okay.  
Jaxon: And then went to the right and found 143.  
India: You know I'm going to call you out on your explanations, so saying looking isn't gonna fly. Alright Rashad, 1e.  
*[Above, India shows that she is aware that the students are not providing explanations of their thinking on their own and reminds them that she expects them to.]*  
Rashad: We got 100.  
India: How'd you get that?  
Rashad: We went to our run time our y in seconds, at the bottom it had 45, and we went to the left and the vertical drop it had 100.  
Mindy: Wait. What?  
India: Okay let him explain again.  
Rashad: Alright, on the right it says 45.  
Mindy: Oh.  
India: Did y'all use the graph?  
Mindy: Yeah.  
India: Does that clarify?

In the next exchange, the students were working on the following problem in Unit 2, Lesson 3, Investigation 2 in Course 2, Smart Promotions, Smart Solutions. The discussion is from an observation in December just a few weeks before the end of the semester. There was evidence of India's students displaying characteristics of Level 2 explaining, as they gave information about their math thinking as India probed them, and volunteered their thoughts sometimes. India's promoted the development of a discourse community in her classroom by asking students to explain their answers, modeling the types of questions she expected her

students to ask, and encouraging them to ask each other questions and later expecting those behaviors. The students were responding to the following problem:

A system of linear equations like you used in Problem 1 or 2 can be represented with matrices. The matrix representation leads to another useful method for solving this problem.

a) Write the two equations, one about the other, in a form like that below.

$$\begin{aligned} \_ b + \_ c &= 3,500 \\ \_ b + \_ c &= 25,500 \end{aligned}$$

b) This system of equations can be represented by a single matrix equation. Determine the entries of the matrix below so that when you do the matrix multiplication, you get the two equations in Part a.

$$\begin{bmatrix} \_ & \_ \\ \_ & \_ \end{bmatrix} \begin{bmatrix} b \\ c \end{bmatrix} = \begin{bmatrix} 3,500 \\ 25,500 \end{bmatrix}$$

India: Alright Jaxon, in 3b, what did you get for your entries that were missing?  
 Jaxon: Okay. My entries, for the first row, we got nine, five and for the second row we got nine, five.  
 India: Do y'all agree?  
*[Some students respond "Yeah."]*  
 Kirsten: No.  
 Jaxon: Yeah. Nine, five. Nine, five.  
*[Kirsten says, "No" again. A student asks, without prompting from India, what Kirsten and her group got.]*  
 India: Kirsten, why do you disagree?  
 Kirsten: Because um in number two, it gives you the order of them, and there's um one, one, nine, five and you plug them in.  
 Group of boys: Huh?  
*[India points to the boys that said "huh" and said, "They didn't hear you Kirsten." Rashad repeats for her, "She said one, one, nine, five."]*  
 Jaxon: One, one, nine, five?  
 Rashad: Yeah, that's what she said.  
 Kirsten: In number two, they give it to you with the  $b$  plus  $c$  equals 3500, that's one and one, and then the 25 five is the nine, five and then from there you just plug them in.

Rashad: That's why kept on putting in b and c, and we just have to put in one, one.  
D'Sean: Well, we got something else.  
Mindy: Yeah, we got something totally different.  
India: What did y'all get?  
Mindy: You probably don't want to know.  
D'Sean: I think ours is right. Alright, you wanna know what we got?  
India: Sure.  
Mindy: Well, they're talking about nines, we're in the thousands.  
India: You put in your answers?  
Mindy: Yeah. We put our answers in. Can you explain it?  
India: Alright on Friday you found the equations right, and you found it to be  $b+c$  to 3500 and what was it, nine b plus five c equals 25,500. Right?  
Now in part 3a, they were basically telling you to fill in the blanks, okay? So they've given you a system. Now you have to fill in the blanks.  
Mindy: Are we supposed to divide?  
India: No, you don't have to divide anything. These are your blanks, right there in front of you.  
Mindy: I don't get it.  
India: You don't get what?  
Mindy: Oh! I get it. I see what you're talking about. The blanks in front of the  $b$ 's and  $c$ 's.  
India: Exactly. Your coefficients. The number in front of the variables. Those are your coefficients. Right?  
India: Stephen, what's the understood number in front of the b if there's not one stated?  
*[Several students respond, "One."]*  
India : Stephen?  
Stephen: One.  
India: One. Thank you. So for now. If I take my matrix, they gave you blanks again, right? I'll rewrite it.  
*[She writes on the board.]*  
India: So this first one, if my equation is gonna equal to 3500, what should these two blanks be here then Abram?  
Abram: Um – I don't know. B? Uh, b?  
India: If this is my system, and I have it equal to 3,500, what should these two blanks be?  
Abram: Um. Can you say that again?  
India: If this is my system, this whole thing, and I'm only dealing with the top one right now, equal to 3,500 and I already have my variables. I'm trying to find my coefficients, so my two numbers. So what two numbers should come here?  
India: One and what?  
Abram: One.  
India: So I should have one, one.

Jacqui: How'd you get those?  
India: From my system, okay? So Jacqui, If I'm dealing with the 25,500, what should come here. This bottom row?  
Jacqui: Nine and five.  
India: Nine and five. And there it is...Questions on how to set it up? You sure?

India sometimes allowed students to lead portions of the whole class discussions after students had worked in groups. During these instances, a student volunteer (or teacher-selected student) would lead the class through the solutions, often pausing after each part of the question to make sure all of the students agreed. India asked her students questions like "Why?" and "What do you mean by that?" She also asked questions like "Is there any discussion?" after answers were given. When her students led discussions, they emulated India's questions. The student-leader would also ask students who did not have the correct answers to provide their solutions. It was also not uncommon for students who had arrived at different answers than other students would interject when they disagreed. Asking if their peers were satisfied with the answer was also common practice in student discussions.

The movement between Levels 0 and 1 in both components occurred quickly and was assisted by the use of the *Core-Plus* curriculum materials and its focus on getting students to explain their thinking. The data collected for this study occurred during the first semester of the academic year, and both teachers were between Levels 1 and 2 at the end of data collection, with India's class demonstrating some evidence of questioning and explaining at Level 2 and sometimes Level 3.

Teaching with *Core-Plus* requires a shift from the teacher as sole authority of knowledge to a role of facilitator of learning amongst their students. Teachers using *Core-*

*Plus* must adjust to facilitating discourse in a way they have not been accustomed. They may struggle at first with getting their students to talk more in class, and once they begin to talk, they may struggle with managing the discussions that result. These struggles include asking questions to elicit student thinking, encouraging students to talk to each other, responding appropriately to students' ideas, and encouraging active participation from all students.

Both teachers had outspoken students in their classes, and it was easy for these students to dominate class discussions as some students sat unengaged. This is evident in the transcripts provided, which were short excerpts from their 90 minute classes. According to an observation report completed by her content specialist, India struggled with keeping the whole class engaged in whole class discussions. She reported that while India's class spent time in whole group discussions, it was difficult to tell if all students were participating. She provided reminded her to check for unengaged students. She wrote in a report, "It was hard to tell how students were invited to give input, but it seemed to be whoever said their opinion out loud and was heard" (9/1/09). She also reported that India was inconsistent and inaccurate as she tried to recognize when students were lost, un-engaged, or showed evidence of a misunderstanding. She wrote, "She would occasionally try to help a student who seemed to have a misunderstanding by questioning them about their ideas. This typically backfired because there was so much input by other students that it was hard to keep focused on the one student" (9/1/09). The outspoken students in India's class were eager to participate and would do so without her prodding. When India asked particular students to answer a question though, she made sure that the students she called on answered the questions she asked

instead of the students who yelled out. Sometimes this meant that the students who she had initially called on repeated the answer or explanation that a student had already yelled out.

Making sure all students were participating in whole class discussions was an issue for Leslie as well. As mentioned previously, she often asked questions of the students who had provided the correct answers in whole class discussion, and it was usually the case that these students were the loudest. During the class observations, there were students who spoke multiple times each class period. Regularly, there were ten students who rarely spoke during a whole class discussion unless she called on them to contribute to the discussions.

### **Students' Reaction to Conducting the Research**

In order to fully consider how the classrooms changed (Research Question 2), one might need to consider if the conduct of the research itself was contributing to changes in participation patterns. While ultimately this is not possible to determine, one can report on the responses of the students to the video-recording. It is important to address the effect the presence of the video cameras and researchers might have had on students' behavior and the entire classroom experience. Generally, the students became more comfortable during the video-recording process. Toward the end of the semester when I visited the classrooms, the students talked freely with me, while after my first visit with Leslie's class, one group of students said having me as a visitor made them "nervous." During some of the first observations, other students made comments about being nervous or not wanting to be on camera. The teachers sometimes noticed that the students were less likely to speak up or ask questions, but as the video-recording occurred more frequently, the students became more

comfortable. India said, after noticing that her students were affected by the video-recording equipment, “[T]he first day, they were hardly getting up and moving around.”

### **Summary**

This chapter presented the findings of the study. The teachers in this study encountered challenges within a variety of areas of implementation of *Core-Plus*. These include adjusting to the curriculum features and materials, developing a collaborative classroom, and facilitating mathematical discourse. The teachers’ weaknesses in content knowledge also affected their ability to navigate the curriculum. Issues of planning and time management were barriers to implementation as well. Chapter Five includes a discussion of the findings and conclusions, and relates the study’s findings to the literature in the area of focus.

## CHAPTER FIVE

### DISCUSSION AND CONCLUSIONS

In this chapter, I discuss the major themes from the findings and their relationship to other research. I also present limitations of the study, draw conclusions, and discuss areas for future research in this area. Next, I present potential implications for both research and practice to include recommendations for the design and refinement of professional development models similar to NCIM. This chapter concludes with a discussion of issues encountered and lessons learned during the research process.

*Core-Plus* is still for the most part considered an innovative curriculum, and districts adopting it should expect to have professional development to help teachers with implementation. The evaluation data (Confrey et al., 2008) showed that the teachers who attended both weeks of the NCIM Summer Institute felt the experience was customized for them. The teachers expressed that they benefitted from attending the Institute and were excited about returning to their classrooms and putting what they learned into action.

Researchers seek to study curricular effectiveness but this cannot be studied without consideration of implementation; however, implementation of a new approach is not simply an alternative to an old approach. The process of implementing a new approach is more complicated, and it requires teachers to get professional development. The most targeted and effective professional development, however, does not imply that the implementation effects will be what is expected or that implementation will occur as intended. This is especially an issue when trying to implement a curriculum like *Core-Plus* in a system in which other elements (i.e., end-of-course testing) are not aligned.



The purpose of this dissertation study was to examine the experiences of teachers who implemented the *Core-Plus* mathematics curriculum after participating in the NCIM Summer Institute. This study was conducted in an effort to study the struggles the teachers continued to have after participating in the professional development and to identify areas in which the professional development helped the teachers. This study's findings can help inform the refinement of the NCIM professional development model or future professional development activities. This study is important because it followed through with some of the teachers and explored what happened in the teachers' classrooms once they returned to their classrooms. It was also important to see to the extent of the teachers' implementation, and in particular, what a discourse framework added to a reform curricula might lead to in terms of changes in teacher practice.

### **Discussion of Findings**

Major shifts in the environments of mathematics classrooms are described in the *Professional Standards for Teaching Mathematics*. These shifts call for a reformed vision of teaching and learning mathematics and are necessary to move from traditional instructional practices to mathematics teaching for the empowerment of all students. The shifts include a move toward mathematics classrooms as mathematical communities in which mathematical reasoning, conjecturing, inventing, and problem-solving occur and not a focus on memorizing procedures and finding the right answers. Regardless of whether teachers try to emulate this experience with reform curricula or not, they will need support to help them develop this type of environment in their classrooms. One could argue that using a curriculum like *Core-Plus* should make it easier to create the type of mathematics classroom

environment described by the *Standards*, but it is unreasonable to expect teachers to make the transition without support. Realizing the significant shift involved with transitioning from teaching single-subject curricula to teaching with *Core-Plus*, the NCIM professional development model was created.

Despite the fact that their implementation lacked certain features, it should be noted that both teachers undertook those efforts in good faith. They were committed to implementing as best as they could, worked for improvements over time and were generous with their time and willingness to participate and share their experiences. The findings of this study continue to support the notion that teachers implementing *Core-Plus* will need professional development in order to be successful using the curriculum. The question explored by research in this area has been what type of support is most beneficial. This study called attention to aspects of the professional development that influenced the teachers most and shed light on areas of implementation that professional development should address. The study also pointed out areas in which the teachers continued to struggle even after participating in the professional development, suggesting that the professional development model should consider a more intense focus on aiding the teachers in their areas of struggle (i.e., planning and timing, content, classroom management, discourse).

The results of this study may also be useful for principals of teachers implementing the curriculum (especially those early in early stages of implementation) as well as school officials considering whether to adopt the curriculum; for they should understand from the beginning that adopting curriculum of this type necessitates that supports are put into place to assist the teachers. These study findings are especially useful for principals who may lack

familiarity with mathematics curricula in general or reform mathematics curricula because while some administrators expect increased student achievement to result from the change to a reform-oriented curriculum, the change in curriculum alone is unlikely to produce the desired results.

Both teachers involved in this study expressed their commitment to the curriculum and aligning their teacher practices to those encouraged by *Core-Plus*. Like teachers in the Kazemi and Stipek (2001) study, both teachers implemented aspects of reform-oriented instruction, on the surface. Their students worked in pairs or small groups; they encouraged their students to explain their work; they made concerted efforts to make the mathematics applicable to their students' lives by making connections to real-world situations; and they attempted to incorporate technology into their instruction. Deeper analyses of their observations and interviews revealed areas of struggle for both teachers. One of the findings from this study was that the teachers' content knowledge affected how they implemented the curriculum. Their struggles with the content made it particularly challenging to manage the discussions in their *Core-Plus* classrooms. One of the teachers expressed that she had learned so much about mathematics since she had started teaching with *Core-Plus*, which supports the research that teachers may learn new mathematics when working with reform-oriented curricula (Lloyd, 2000).

The teachers also struggled with questioning and interacting with students in both whole group discussions and group work among the students. Both teachers set as a goal for their students to talk more in class discussions, but the findings from the observations and interviews indicated that the teachers focused a great deal on the amount of student talk, but

evidence of their focus on the quality of student talk was lacking. With that, the idea of student discourse should be examined further with teachers. These conversations around student discourse should include a discussion of whether discourse simply means that the substance of the conversations should be considered when trying to promote student discourse.

Evident from this study was that teachers asked questions, sometimes good questions, but student-to-student discourse was not facilitated because the teacher still maintained control of the classroom. It was interesting that both teachers made comments that their classes “didn’t require as much because they talked.” This sentiment begs the question of how the teachers perceived questioning and whether they considered that the goal of questioning was to elicit student thinking. Often once the students provided the right answer, the teacher stopped her questions. Deciding when to help students and when to allow them to struggle was a challenge for one of the teachers especially, as she expressed that she wanted her students to rely on each other when working collaboratively rather than seeking her out for help first.

From the video observations and interviews, it is clear that some of the teachers’ most pressing challenges were in the areas of timing and planning for the course, even after participating in the professional development. Trying to fit the entire course in during the school year in time for testing was a concern of the teachers. The school calendar and testing requirements were the cause of their concern. If teachers were able to use their time more efficiently during each class period at the beginning of the year (i.e., reducing the amount of time off-topic and better managing the groups while working), they could eliminate some of

the timing pressures. Leslie was fortunate to have the same students both semesters, so trying to complete both courses in one year (Course 1 in a semester and Course 2 in another semester) was less of a strain on her than for India because her students went to different teachers the next semester. An issue to consider is whether teaching with *Core-Plus* is best on a block or traditional schedule. India expressed concern over having students who had not had mathematics for six months because of their semester schedule.

What is clear from the findings of this study is the connection between managing the classroom and the pressures the teachers feel regarding time management. Students spent a considerable amount of time working together in groups. Teachers making the transition need help learning how to make groups of students “work.” During my observations, student groups did not always use their allotted time efficiently, and the teachers had to redirect off-task behaviors. This sometimes resulted in significant amounts of time wasted. The time wasted from students being off-task can take away from the time allotted for material to be covered for the year. If the teachers would better manage the groups on a daily basis, the cumulative time saved each day could be considerable.

One of the most consistent findings is how the pressures of end-of-course testing influenced the implementation of the curriculum and what mathematics the teachers chose to focus on. Teachers used supplemental materials, which more closely resembled a traditional mathematics textbook, when they felt their students needed more practice with a particular topic even though the content specialists suggested that teachers not supplement *Core-Plus* with traditional workbooks. This begs the question whether some teachers see curricula like

*Core-Plus* as a viable option only after their students already have exhibited sufficient competence with topics, not as a means to teach them those topics.

### **Study Limitations**

The use of the Math-Talk Learning Community framework (Hufferd-Ackles et al., 2004) guided some parts of this study. The choice of framework can be considered a limitation for this study because it directed what received attention. Only collecting data during the first semester of the academic year is also a study limitation. In the interest of maintaining the same context, the decision was made to collect data during a semester realizing that the next semester the teachers would be teaching a different course with a different group of students. This was only the case with India, however, because Leslie kept her same students, in the same class periods the entire year. I also acknowledge that collecting data over the entire school year would have strengthened the study. Certainly, it is probable that as the school year went on, the teachers became more comfortable in their role as facilitator and allowing their students to struggle with some of the material.

I also acknowledge that observing the same class for each teacher limits this study. Again, one reason I made this decision was out of consideration of context. The teachers chose the class, period, and lessons for observations. They also shared during the post-observation conferences, experiences they had with their other classes. Last, my choice of multiple observations for a small number of teachers versus a smaller number (perhaps even one) of observations for a larger number of teachers may be viewed as a limitation. I chose depth over breadth in this situation in the interest of gaining an in-depth understanding of the teachers' experiences.

## Conclusions

Across the nation, districts are adopting reform curricula, and evidence is building that students are benefitting, but how teachers enact the curricula influences students' achievement. Districts may adopt new curricula in an effort to increase student achievement, but could become frustrated if achievement gains do not result. Because research has shown that a curriculum's effectiveness depends on how the curriculum is enacted (NRC, 2004), one would want to be certain that the student achievement outcomes were not influenced by uneven implementation of the curriculum. What we know for sure is that teachers will need professional development to implement *Core-Plus* appropriately. The findings of this study support the idea that simply giving teachers a new curriculum and expecting them to teach it according the authors' intentions is unlikely to happen (Arbaugh et al., 2006; Lloyd, 2000).

If the belief is that increasing students' understanding of mathematics is achievable through the use of curricula like *Core-Plus* and that the result will be increased student achievement, then attention needs to be paid to what is happening in the classrooms where *Core-Plus* is used (Arbaugh et al., 2006). The more knowledge about teachers' experiences and struggles with the curriculum we possess, the better equipped we are to design necessary support systems to aid teachers in the transition to the curriculum and the type of instruction suggested by the NCTM *Standards* documents. Professional development must be viewed as a critical part of the curriculum adoption process, and should continue throughout the year.

The NCIM project shows potential for this type of model and the effect it can have on teachers' practice. Through the interviews and the observations, it is apparent that over time the teachers involved with the project made improvements. Perhaps when working with

teachers all new to the curriculum, a one-size-fits-all approach would work for professional development, but even then teachers enter their classrooms with different levels of knowledge and understanding, experiences, and beliefs about how to teach mathematics and how students should learn mathematics – all of which affect the instructional decisions they make.

The NCIM approach allowed teachers to receive customized professional development through the content specialist visits and the summer conferences, as they were created with the teachers' concerns in mind. By incorporating content specialist reports and comments from teachers on the evaluations, the project team was able to customize a model to address the teachers' needs in the context of their classrooms. The two cases presented provide evidence that teachers can make progress and that the professional model made a difference. Not all teachers will experience the same level of success, so further research should investigate what makes some teachers more successful than others. This study confirms what others have shown - that simply handing teachers this curriculum and expecting them to teach will not lead to implementation as intended by the curriculum authors.

One may also infer from this study that teachers' development of discourse communities can be changed through self-reflection using video-recording. The changes the teachers made were influenced by their interactions with me even though I did not provide feedback. The opportunities to reflect on the day's events in the post-observation conferences appeared to influence the teachers' growth, or at least their self-awareness. Their progress suggests that self-reflection can help change teachers' questioning strategies and help them



implement *Core-Plus* in general. It is probable that the time the teachers spent with me watching themselves teaching on video and reflecting caused them to consider their behaviors in ways they would not have otherwise. While teachers' reflecting on their practice in this study appeared to bring about changes in their instruction, creating a structured intervention around reflection to include giving feedback could help teachers improve their practice, especially their questioning techniques, even more. Expanding the reflection component to include transcribing the questions teachers ask in their video-recordings has the potential to cause teachers to pay even closer attention to what they say in class.

Hufferd-Ackles et al. (2004) suggested that more research attend to what happens during the transitions between the levels of the components and how to more effectively assist teachers with making the transition. Although the teachers involved in this study were not provided with feedback from me regarding their instruction, the experience of reflecting with video and the math-talk learning community framework proved useful. The need continues to explore the various kinds of professional development that help teachers implement reform curricula and develop a math-talk learning community in their classrooms.

### **Implications for Policy and Practice**

We ask ourselves the question, "Given what we have learned about teachers and their experiences implementing *Core-Plus*, how do we design authentic and worthwhile professional development activities for them?" The current study is significant for use in both policy and practice. It is important to remember the context in which this study was conducted. The two teachers taught in schools in rural communities, schools that typically are not able to attract and keep the most effective teachers. Both teachers were natives of the

areas in which their schools were located, and they had returned to teach after completing their undergraduate degrees. With the goals of increasing student achievement in these communities and attracting the most qualified teachers to these areas, an important policy consideration is how to attract more effective and qualified teachers to rural communities. Providing teachers with incentives to teach in areas they would not typically go is a way to attract more qualified teachers to these harder to staff communities.

Based on the data collected in this study, there are implications for three groups: professional development directors, school and district administrators, and teachers. Recommendations for the three groups are discussed in this section.

### **For Professional Development Designers**

Conducting this study has provided findings that inform the design and implementation of professional development for teachers. A recommendation for professional development designers is that professional development programs for teachers of reform mathematics curricula include an intense focus on the content. The findings of this study, especially some of the examples of India's teaching, suggest that there is an interaction between the discourse teachers are able to successfully facilitate and their understanding of the content.

While the NCIM professional development model is lauded by the teachers involved, the model can be improved to provide more assistance to the teachers. The data collected in this study suggests that there should be more explicit attention to the mathematics content. Teachers need mechanisms for them to learn or re-learn mathematics content. Understandably, this is challenging given the desire to treat teachers as professionals, but

there is a need to enhance the content knowledge of teachers who will be teaching with the Core-Plus. The recommendation for a greater focus on content knowledge stems from that concern. While the teachers who participated in the NCIM Summer Institute were afforded the opportunity to work through the investigations as students, opportunities for deeper discussions about the content, discussions that would have really addressed the conceptions about mathematics the teachers and some of their content weaknesses should be created. This is not to say that professional development activities should focus solely on the content before introducing teachers to the curriculum because the distinction between content and pedagogy becomes inappropriate when teaching with a curriculum like *Core-Plus*. Instead, discussions of content should occur within the context of the lessons in the curriculum. Without an understanding and faculty of both content and pedagogy, teachers will not be able to facilitate productive discourse or lead students through the investigations within the curriculum.

The findings of Arbaugh et al's (2006) research supported the need for professional development, but the question remained whether the professional development activities needed to be "textbook-specific" (p. 544). This study supports the notion that it does. This research suggests that professional development activities should provide teachers opportunities to work through the actual material in the curriculum and work on discourse practices using the same material instead of just having general conversations. Teachers are provided the opportunities to learn about curriculum while using the materials, and they also might need to learn or re-learn mathematics while working with the materials (Lloyd, 2000). For most teachers when they teach with reform-oriented curricula they have to revisit

mathematical ideas they learned as students and extend their knowledge and understanding. Some teachers might even be introduced to entirely new mathematics altogether.

The professional development for teachers transitioning to *Core-Plus* from single-subject mathematics should include opportunities for teachers to focus on their cooperative and collaborative group techniques so that there can be more effective use of time. Teachers may need guidance in how to manage students who do not participate and students who are off-task, as well as how to keep the workload balanced for the students in the groups. Measures for holding the groups accountable should also be discussed and practiced. Opportunities should be included for the content specialists to co-teach with the teachers instead of just visiting, observing, and writing a summary at the end of the visit and e-mailing to the teacher - a summary that may or may not be revisited after the initial reading.

When teachers implementing *Core-Plus* in schools where they are one of a few mathematics teachers, if not the only mathematics teacher, a great concern is the lack of learning communities to gather around some of these issues with which the teachers struggle. Research has suggested that collaboration between teachers is helpful when implementing the *Core-Plus* curriculum and for improvement in instructional practices period. The teachers in this study sometimes collaborated with other mathematics teachers at their school, but a suggestion for individuals who design professional development is to include opportunities for teachers to engage with each other throughout the academic year and not just at the summer workshops. There is the strong likelihood that learning communities would assist with an easier transition to teaching with *Core-Plus*, and perhaps discussions of the mathematics content would occur as well. The utility of virtual learning communities should

also be explored in situations like these. Teachers could use a number of videoconferencing tools develop these communities and participate in activities similar to those of the teachers and content specialists in this study, including video-recording themselves and posting for other teachers to comment on. Follow-up professional development should also be included with trained facilitators with experience with the curriculum. Facilitators could also participate in the virtual learning communities. The assistance provided could possibly be even more valuable if the facilitators, expert teachers, coaches, or content specialists had experience teaching in school environments similar to those of the teachers they are assisting. Teachers could also use these learning communities to plan with other teachers.

Because the teachers felt that they benefited from viewing the videos and reflecting during the post-observation conferences, a professional development model designed to change teachers' instructional practices should include opportunities for teachers to view themselves on video and reflect. According to Lloyd (2000), teachers through watching videos may learn to more carefully observe and listen to students, thus expanding their conceptions of students and how students learn mathematics. Even more because the teachers benefitted so much from getting feedback from other teachers at the workshop, the implications for having a similar professional development experience throughout the year are great. Opportunities for the teachers to view themselves on video and reflect and share with other teachers and receive feedback appears to be a powerful structure for professional development of this type.

Professional development activities should also incorporate means to hold teachers accountable for evaluating their progress. It was difficult for the teachers in this study to

arrange time for reflection. Understandably, required duties and other time constraints restricted the time teachers spent engaged in reflective activities. Because I chose to take a non-participatory role in the interviews, the reflections the teachers shared were only their impressions and perceptions. There could be more structure for the discussion and reflection activities also led by a trained facilitator. Viewing the videos in small groups would provide the opportunities for discussion including other teachers' perspectives as well. It would be easier in this venue to discuss issues that arose in instruction, including those of content. The teachers would be able to share their strategies for dealing with particular issues that arise in instruction. Because it is sometimes the case that teachers are hesitant to criticize other teachers, it would be helpful to provide structure or guidelines for having discussions as well to have a preliminary discussion about the purpose of the small group. It is also possible to create a structure during which teacher comment anonymously on other teachers' videos.

The teachers who attended the Summer Institute (included the two in this study) listed ways they would assess their progress with their goals, but with no accountability. Of course, while operating within all of the other constraints and demands that accompany teaching, they did not follow through with all aspects of their plans. Because these types of activities always receive positive responses on the evaluations of the summer workshop, it is likely that incorporating a system in which these experiences could be incorporated would be a beneficial addition to the professional development model. This community would especially be valuable to those teachers who are isolated in their schools, either because their mathematics department is small or because their colleagues have not bought into the idea of reform mathematics teaching or reform-oriented curricula.

Teachers should be provided assistance with appropriate (if any) supplementation of the curriculum, if the goal is to use the curriculum alone. Unfortunately, this presents an interesting dilemma, because if the goal is for students to show increased performance on standardized testing, then it is understandable how a teacher might feel justified in supplementing the curriculum with material he or she feels is important for the testing.

### **For Administrators**

The main suggestion for principals and other school officials is that they should consider the need for and role of professional development when adopting the *Core-Plus* curriculum materials. As other research has suggested, school officials are cautioned against thinking that the adoption of the curriculum alone will bring about the improvements in student achievement desired. Teachers will need more than just a summer workshop, so the professional development plan should also include some kind of follow-up for the teachers. It is important that district/school officials be involved in the professional development so that they are able to tell what implementation looks like. Administrators should also be aware of the type of implementation they desire, whether it be full implementation or traditional classroom with the integrated text.

School administrators, if adopting *Core-Plus*, must consider resources for professional development. Administrators also need to consider the resources the teachers will need to implement the curriculum. While certainly interactive white boards, computers, and data projectors are not as essential for teaching with the curriculum as graphing calculators, there is an emphasis on technology and access to these tools help enhance instruction. A feature of the curriculum is its focus on and encouragement of multiple

representations (i.e., verbal, numerical, graphical, and symbolic), and the use of technology permits this emphasis (Coxford et al., 2008, p. xi). Thus, when students have limited access to technology, they are limited in the representations from which they may select. Without access to at least a computer and data projector, the students would also be prevented from using the curriculum's computer software CPMP-Tools®, which they also use to solve problems.

Research has shown that teachers' beliefs change as they begin to teach with the *Core-Plus* materials (Arbaugh et al., 2006; Lloyd, 1999, 2002; Wilson & Lloyd, 2000) and that their beliefs are related to the instructional decisions they make. If maintaining two paths for mathematics curricula, school officials are advised to select the teachers whose beliefs align with *Core-Plus* or who have demonstrated that they are committed to teaching mathematics in a new way. If opting for a whole school adoption of *Core-Plus*, extensive professional development opportunities must be sought for all teachers. It is best for these professional development activities to continue throughout the year, especially in early years of implementation. Opportunities for teachers to collaborate and plan with each other can be provided and encouraged during the school day, if possible, to make it easier for teachers to collaborate.

Principals are encouraged to attend professional development activities with their teachers to become knowledgeable about the curriculum. Those who do not consider themselves “strong” in mathematics or with a limited knowledge of mathematics education in particular, might benefit from participating in at least a portion of the professional development activities with their staff. This participation could prove especially beneficial to



principals who are not familiar with reform-oriented mathematics instruction. Suggesting that principals be involved in the professional development is not as a suggestion that all principals should be experts in mathematics or every content area. Given the nature of reform-oriented curricula and the risk of mistaking superficial implementation of the curriculum for good teaching, principals should be educated so that they understand reform instruction practices in mathematics and so that they are more equipped to make decisions and negotiate between mandates from the district and state and what the curriculum calls for in its implementation.

This study also demonstrated the promise of using video-recording and post-observation conferences as a means for evaluating teachers. Principals when doing observations could possibly use the method of video-recording and watching with teachers as an evaluation tool. Partnering with mathematics department chairs might also be a helpful way to conduct teacher evaluations when using *Core-Plus*.

## **For Teachers**

### **Adjusting to the structure and features**

Teaching with *Core-Plus* requires teachers to make two significant adjustments in which teachers may encounter challenges, promoting collaborative learning within and among student groups and facilitating discourse. Regarding facilitating collaborative learning, teachers should anticipate the challenges they might experience with their students working in groups more often and address them. Teachers will need to become comfortable with not spending the majority of their time at the board lecturing. Using videos of their

instruction and student group work in reflective activities shows promise for helping teachers make this adjustment.

### **Collaboration**

The findings of this study and the project's evaluation reports suggest that teachers would benefit from collaborating with other teachers. Again, it is understood that factors over which teachers have no control may make it challenging for some of these activities. When possible though, teachers should make concerted efforts to work with other teachers, including both experienced and less-experienced *Core-Plus* teachers. They should seek out more experienced teachers for assistance, but also maintain communication with less-experienced teachers to share frustrations and successes, so that they realize their experiences are not unique to them. Teachers should take advantage of (or create opportunities) to plan with other teachers teaching same content. Teachers were eager for presentations and resources from the Summer Institutes and throughout the year to be posted and shared on the NCIM website, suggesting that teachers will also benefit from sharing strategies, advice, and resources.

### **Content weaknesses**

Switching to teaching with *Core-Plus* from a traditional mathematics curriculum will likely mean teaching new content for some teachers. Teachers should identify areas in the mathematics that they would not consider their strengths or have these areas identified for them. The averages of teachers' scores on the content knowledge assessment from the Summer Institute if considered on a 10-point grading scale, were less than passing. While the assessment was designed to cover material spanning the three courses of the curriculum, and

while the hope would be that all high school teachers would know the content of the entire curriculum, the scores are disturbing and show that the teachers have gaps in their content knowledge.

Teachers may find that content knowledge that sufficed for teaching a traditional curriculum is not enough for teaching this curriculum. Managing the discussions requires a greater hold on the content, because of the increased focus on students' explanations and the teacher needs to be able guide the direction of the lesson while incorporating student ideas and thinking put forth in their explanations. No longer is the teacher simply focused on right answers. Teachers accustomed to teaching only the Geometry concepts or only the Algebra 1 concepts, may struggle when adjusting to teaching out of their comfort zone. Since *Core-Plus* covers discrete topics and statistics and probability, some teachers may need to re-learn or learn completely new material. After identifying and accepting their weaknesses, teachers should seek assistance with content they are uncomfortable with. Teachers should also review the courses they are not planning to teach as well. This review will help teachers recognize the connection between the courses and the development of topics over the courses.

### **Student learning**

Teachers who are successful with this curriculum believe that their students can learn using the curriculum. While it is understandable that teachers might be skeptical with new techniques or resources, research has illustrated that the teachers with confidence in the curriculum have higher levels of curriculum implementation. Teachers can increase their confidence with the curriculum by increasing their comfort with the curriculum. This could

engaging with the curriculum materials, planning for instruction using the materials, or visiting the classrooms of teachers who are implementing *Core-Plus*.

In both teachers' classrooms, there was a need to strike a balance between encouraging participation from all students, and monitoring and controlling the more boisterous students without alienating them. Keeping the classroom moving is less challenging when the teacher has active and eager participants, but continuing to respond only to the same students who participate may not promote participation for the less outspoken students. An informal means of keeping track of participation would be helpful, as the goal is distribute the participation patterns, engaging all students appropriately while not stifling the energy of the eager students.

When using a curriculum like *Core-Plus* because it requires a shift in the role of the teacher in the classroom, teachers might reevaluate their perception of what it means to "teach." If there is still the idea that the teacher will need to teach students material or concepts to which they have had no prior exposure or that might be considered "new," then the teacher remains the sole authority of knowledge and the idea is that the students are incapable of learning without the teacher and direct instruction. This is not the idea of *Core-Plus*. Teachers will need to learn to trust that their students are capable of learning without teaching everything explicitly. Teacher may also need to learn to understand their students' ideas and use their ideas to basis for discussions.

### **Reflection and growth**

The teachers in this study attempted to incorporate reflection into their routines, but the only times they engaged in reflective activities. The teachers indicated that they would

assess their progress through reflection, but obstacles prevented such reflection. Realizing that the school day is full of activities, duties, and other responsibilities, teachers still need time to become more conscious of their practices. It would be beneficial for their day to include opportunities for them to plan and reflect, to include setting goals and finding ways to assess themselves with the understanding that deliberate efforts to improve are required.

The results of this study showed the promise of using video-recordings and reflection for making improvements. Flip-cameras are a relatively inexpensive way to record instruction and even watching the clips alone and reflecting can prove beneficial. Opportunities to reflect with a partner or group of teachers would be even more valuable.

### **Areas for Future Research**

This study has indicated that NCIM professional development was able to promote changes in instruction among participants, especially those who received the one-on-one guidance from the content specialists. The NCIM model has shown that it is both sustainable and scalable to reach more teachers with the increase of the number of content specialists and/or including a component focused on equipping a lead teacher at each school. Another possibility is for a teacher in the region to assume some of the observation duties of the content specialists.

Additional research is recommended in the area of changing teacher practices to align more with reform curricula and exploring possibilities for redesigned professional development to support the implementation of reform-oriented curricula. One of these areas is teacher questioning and helping teachers develop a discourse community. The results of this study show the promise of using videos of instruction and reflection as a professional

development tool with other teachers and schools. Given the gains Leslie and India made in this study during the post-observations conferences and the follow-up conversations with the content specialists, another area of research should investigate the changes in instruction and growth in content that can occur as result of participating in professional development activities including a reflection component and greater attention to the mathematics.

At some point, research should explore the link between teacher questioning and student achievement. More research is warranted to explore ties between instructional practices and student learning outcomes. A recommendation for future study is to examine the differences in EOC testing of students in single-subject course and *Core-Plus*, and whether there are differences based on level of implementation of the curriculum and professional activities of the teachers. Recognizing that teachers' beliefs mediate the relationship between the textbook and their instructional practices, there is also a need to pay closer attention to teachers' beliefs about curriculum materials, mathematics, and how students learn mathematics. There is also a need to explore further the relationship between teachers' content knowledge and their ability to successfully navigate reform-oriented curricula. The most considerable recommendation is for future research to investigate the links between teacher content knowledge, participating in professional development activities to support reform mathematics curriculum implementation, level of implementation, and student achievement.

### **Researcher's Reactions**

Conducting research of this type raises a number of concerns. One to consider when conducting classroom observations like I did in this study, is that the teachers may feel

compelled to implement activities or exude behaviors that they think the researchers are looking for during the visit and these activities and behaviors would actually be out of the ordinary for the teachers and their students. Video-recording the observations may make this a greater concern, because the presence of the video cameras, especially if the teacher is not used to being recorded, may make the observation seem more formal or critical. This concern diminishes with the amount of time the researcher spends observing and video-recording. In effect, as the teachers and students become more comfortable with having a visitor and the being recorded, the classroom dynamics were less affected by our presence.

I made notes that the process of reflection for these teachers was an interesting process. What is most important to examine is the culture of reflection and how teachers view reflection and collaboration. The teachers do not appear to be the biggest fans of watching themselves on the video at first, but judging by Leslie's remarks - "This is very painful, but it's good. I like to have any advice - or even just watching this of course I can see little things that I need to work on. I mean it's not fun to watch yourself, but it helps." The implication from Leslie's comments is that also after time, the teachers will see the value in the activity and not fear it as much because of its value.

I noticed during the reflections that the teachers never commented that they noticed anything positive, which was somewhat troubling. This was troubling because reflection does not have to be negative or critical. Some teachers were silent during moments that another teacher might view as an opportunity for critical analysis and growth, and it is probable that teachers felt their behaviors and decisions were positive, hence the non-response. Perhaps more attention needs to be paid to how teachers view reflection of this type in their

profession. When asking teachers to reflect on their teaching, is there an underlying connotation of “think of all the things you’re doing wrong and need to correct?”

Part of the question with teachers and reflection is determining whether it is a lack of self-awareness or self-protection or lack of trust. There is the question of what makes the teachers change some things and not others. They noticed that they said the word “okay” too much or did not allow enough time for a student to answer a question or that they should walk around the room more, but not other times, an error in the mathematics for example. The question is whether they notice the errors and mistakes and choose not to comment on them or whether they do not recognize the errors as errors. In any case, because the teachers made changes in their instructional practices after having watched themselves on video, the idea of having teachers watch videos of themselves or others teaching around discussion would likely be a positive experience for teachers, and that reflection of this type is shows potential for helping teachers improve their practice.

### **Summary**

This study examined a professional development model (NCIM) designed to have an effect on how teachers implement a reform mathematics curriculum, a curriculum which promotes teachers to develop discourse communities and a shift from teacher to student-centered instruction. This study was conducted as part of a larger project that evaluated the effectiveness of the NCIM professional development. The focus solely on content and teachers working through the material as students was inadequate, as teachers wanted to know more about “how” to implement the curriculum. Even with the exposure to the ideas presented in both weeks of the professional development, teaching with *Core-Plus* can still



be challenging. One of the greatest challenges and goals of teaching with the curriculum is the development and facilitation of a discourse community, in which all students actively participate and all students' thinking is valued. Creating this discourse community, relinquishing control and allowing the students to assume responsibility for their learning, and student engagement are at the core of implementing a reform-oriented curriculum like *Core-Plus*. The findings of this study, though, demonstrate that the activities of the NCIM professional development model were worthwhile in helping teachers implement *Core-Plus*, but that they could be improved upon to make an even more effective experience.

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## APPENDICES

## Appendix A

### *Levels of the Math-Talk Learning Community: Action Trajectories for Teacher and Student*

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Overview of Shift over Levels 0-3: The classroom community grows to support students acting in central or leading roles and shifts from a focus on answers to a focus on mathematical thinking.

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<b>A. Questioning</b>	<b>B. Explaining mathematical thinking</b>	<b>C. Source of mathematical ideas</b>	<b>D. Responsibility for learning</b>
Shift from teacher as questioner to students and teacher as questioners.	Students increasingly explain and articulate their math ideas.	Shift from teacher as the source of all math ideas to students' ideas also influencing direction of the lesson.	Students increasingly take responsibility for learning and evaluation of others and self. Math sense becomes the criterion for evaluation.

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Level 0: Traditional teacher-directed classroom with brief answer responses from students.

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<b>A. Questioning</b>	<b>B. Explaining mathematical thinking</b>	<b>C. Source of mathematical ideas</b>	<b>D. Responsibility for learning</b>
<i>Teacher is the only questioner. Short frequent questions function to keep students listening and paying attention to the teacher.</i>	<i>No or minimal teacher elicitation of student thinking, strategies, or explanations; teacher expects answer-focused responses. Teacher may tell answers.</i>	<i>Teacher is physically at the board, usually chalk in hand, telling and showing students how to do math.</i>	<i>Teacher repeats student responses (originally directed to her) for the class. Teacher responds to students' answers by verifying the correct answer or showing the correct method.</i>
Students give short answers and respond to the teacher only. No student-to-student math talk.	No student thinking or strategy-focused explanation of work. Only answers are given.	Students respond to math presented by the teacher. They do not offer their own math ideas.	Students are passive listeners; they attempt to imitate the teacher and do not take responsibility for the learning of their peers or themselves.

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Level 1: Teacher beginning to pursue student mathematical thinking. Teacher plays central role in the math-talk community.

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A. Questioning	B. Explaining mathematical thinking	C. Source of mathematical ideas	D. Responsibility for learning
<i>Teacher is the only questioner. Short frequent questions function to keep students listening and paying attention to the teacher.</i>	<i>No or minimal teacher elicitation of student thinking, strategies, or explanations; teacher expects answer-focused responses. Teacher may tell answers.</i>	<i>Teacher is physically at the board, usually chalk in hand, telling and showing students how to do math.</i>	<i>Teacher repeats student responses (originally directed to her) for the class. Teacher responds to students' answers by verifying the correct answer or showing the correct method.</i>
Students give short answers and respond to the teacher only. No student-to-student math talk.	No student thinking or strategy-focused explanation of work. Only answers are given.	Students respond to math presented by the teacher. They do not offer their own math ideas.	Students are passive listeners; they attempt to imitate the teacher and do not take responsibility for the learning of their peers or themselves.

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Level 2: Teacher modeling and helping students build new roles. Some co-teaching and co-learning begins as student-to-student talk increases. Teacher physically begins to move side or back of the room.

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A. Questioning	B. Explaining mathematical thinking	C. Source of mathematical ideas	D. Responsibility for learning
<i>Teacher continues to ask probing questions and also asks more open questions. She also facilitates student-to-student talk, e.g., by asking</i>	<i>Teacher probes more deeply to learn about student thinking and supports detailed descriptions from students. Teacher open to and elicits multiple strategies.</i>	<i>Teacher follows up on explanations and builds on them by asking students to compare and contrast them. Teacher is comfortable using</i>	<i>Teacher encourages student responsibility for understanding the mathematical ideas of others. Teacher asks other students</i>

<i>students to be prepared to ask questions about other students' work.</i>		<i>student errors as opportunities for student learning.</i>	<i>questions about student work and whether they agree or disagree and why.</i>
Students ask questions of one another's work on the board, often at the prompting of the teacher. Students listen to one another so they do not repeat questions.	Students give information about their math thinking usually as it is probed by the teacher with some volunteering of thoughts. They begin to stake a position and articulate more information in response to probes. They explain steps in their thinking by providing fuller descriptions and begin to defend their answers and methods. Other students listen supportively.	Students exhibit confidence about their ideas and share their own thinking and strategies even if different from others. Student ideas sometimes guide the direction of the math lesson.	Students begin to listen to understand one another. When the teacher requests, they explain other students' ideas in their own words. Helping involves clarifying <i>other</i> students' ideas for themselves and others. Students imitate and model teacher's probing in pair work and in whole-class discussions.

Level 3: Teacher as co-teacher and co-learner. Teacher monitors all that occurs, still fully engaged. Teacher is ready to assist, but now in more peripheral and monitoring role (coach and assister).

<b>A. Questioning</b>	<b>B. Explaining mathematical thinking</b>	<b>C. Source of mathematical ideas</b>	<b>D. Responsibility for learning</b>
<i>Teacher expects students to ask one another questions about their work. The teacher's questions still may guide the discourse.</i>	<i>Teacher follows along closely to student descriptions of their thinking, encouraging students to make their explanations more complete;</i>	<i>Teacher allows for interruptions from students during her explanations; she lets students explain and "own" new strategies.</i>	<i>The teacher expects students to be responsible for co-evaluation of everyone's work and thinking. She</i>

	<i>may ask probing questions to make explanations more complete. Teacher stimulates students to think more deeply about strategies.</i>	<i>(Teacher is still engaged and deciding what is important to continue exploring.) Teacher uses student ideas and methods as the basis for lessons or miniextensions.</i>	<i>supports students as they help one another sort out misconception. She helps and/or follows up when needed.</i>
Student-to-student talk is student initiated, not dependent of the teacher. Students ask questions and listen to responses. Many questions are “Why?” questions that require justification from the person answering. Students repeat their own or other’s questions until satisfied with answers.	Students describe more complete strategies; they <i>defend</i> and <i>justify</i> their answers with little prompting from the teacher. Students realize that they will be asked questions from other students when they finish, so they are motivated and careful to be thorough. Other students support with active listening.	Students interject their ideas as the teacher or other students are teaching, confident that their ideas are valued. Students spontaneously compare and contrast and build on ideas. Student ideas form part of the content of many math lessons.	Students listen to understand, then initiate clarifying other students’ work and ideas for themselves and for others during whole-class discussions as well as in small group and pair work. Students assist each other in understanding and correcting errors.

*Note.* Adapted from “Describing Levels and Components of a Math-Talk Learning Community,” by K. Hufferd-Ackles, K.C., Fuson, and M. G. Sherin, 2004, *Journal for Research in Mathematics Education*, 2, pp. 88-90).



## Appendix B

### NCIM Post-Observation Teacher Interview Protocol

#### PART ONE

**First Interview** [Note: The first interview will ask questions related of things considered static (i.e., demographic information). These questions will not be repeated during subsequent interviews.]

#### **Career History:**

1. How long have you been teaching at (name of school)?
2. Were you teaching before? Where? How long? What subjects have you taught?

#### **Experiencing mathematics:**

1. Please describe your enjoyment of mathematics as a student.
2. What are your feelings towards mathematics now?
3. Can you identify students in your class(es) who you think possess similar feelings? How do you interact with them?
4. How do you think students best learn mathematics?

#### **Instructional Practices:**

1. What do you feel is the teacher's role (your role) in the classroom?
2. How do you assign students to work in groups?

#### **Reform Mathematics:**

1. What comes to mind when you think about reform mathematics and the *Core-Plus* curriculum?
2. What have your experiences teaching *Core-Plus* been like?
3. What are your feelings toward *Core-Plus*?
4. How comfortable are you with teaching the *Core-Plus* curriculum?
5. Have you taught a traditional mathematics curriculum before? Describe your experience teaching a traditional mathematics curriculum.
6. Is there anything about *Core-Plus* that does not fit with your visions of teaching and learning mathematics?
7. Do you feel there are any difference between how students learn mathematics in *Core-Plus* classrooms and student in traditional mathematics classrooms? If so, what are they?

**Subsequent interviews:** [These questions will also be asked in the first interview in addition to the questions presented earlier.]

1. What is planning like for teaching with *Core-Plus*?

- a. Do you find yourself planning more (or less) than you have in the past when you taught using a different curriculum?
  - b. What types of things do you think about when you're planning?
  - c. How do you decide which investigations/lessons to teach?
  - d. Are there lessons that you've found more difficult than others to implement? Would you provide examples?
  - e. Do you collaborate with other teachers when planning? If so, what is that like?
2. How are students responding to *Core-Plus*?
    - a. Do you think there's an adjustment period? If so, what's it like?
    - b. What do students have to get used to?
  3. How are parents responding to *Core-Plus*?
  4. How comfortable are you teaching *Core-Plus*?
    - a. What do you think is necessary to increase your comfort with the curriculum?
    - b. Have you encountered any hindrances? If so, what have those been like?
    - c. Have you ever struggled teaching with the content in any *Core-Plus* lesson or investigation? If so, how did you work through it?
    - d. Do you use other materials besides the *Core-Plus* curriculum materials?
      - i. If so, which ones?
      - ii. Why do you feel like these materials are necessary? What's your motivation for their use?
  5. How often do students talk about mathematics in your class(es)?
    - a. Do you try to get students to talk more about mathematics? How? Can you describe that process?
    - b. What types of norms did you establish at the beginning of the school year?
    - c. How did the students respond?
  6. Please describe your experiences with your content specialist this year.
    - a. What types of things do you discuss with her?
    - b. Are the visits from your content specialist valuable? What do you find valuable from your interactions?
    - c. Is there anything you would like to discuss with your content specialist that you don't?

## **PART TWO**

After the researchers select excerpts for the teachers to view and reflect on, they will be asked questions focusing on three areas: classroom discourse, the teacher's roles, and student thinking. The questions will elicit the teachers' perceptions and thoughts about events occurred during instruction. The questions will be of the nature of the questions listed below, but cannot be determined exactly in advance.

1. What did you notice?
2. What is your interpretation of what took place?

Adapted from Sherin, M., & van Es, E. A. (2005). Using video to support teachers' ability to notice classroom interactions. *Journal of Technology and Teacher Education*, 13(3), 475-491.

## Appendix C

### GOAL SETTING

Name: \_\_\_\_\_

Date: \_\_\_\_\_

My goals are:

Steps that I will take to reach these goals:

Data I will collect:

How will I assess my progress:

## Appendix D

### Personal Reflection

I consciously work on developing a math-talk learning community in my class:

occasionally                       fairly often                       at every opportunity

My math class is a math-talk learning community

usually                       sometimes                       hardly ever

What challenges or obstacles hinder me from making my class a math-talk learning community, at every opportunity?

Self-Assessment: (Hufferd-Ackles, Fuson, and Sherin, 2004)

My class is here on the continuum of becoming a Math-Talk Learning Community in each of the four categories.

<b>Levels of the Math-Talk Learning Community: Action Trajectories for Teacher and Student Levels 0-3</b>			
Questioning	Explaining Mathematical Thinking	Source of Mathematical Ideas	Responsibility for Learning

Other ideas and thoughts I have after hearing the comments of my peers:

Adapted from:  
Connecting Practice and Research in Mathematics Education Professional Learning Guide & Hufferd-Ackles, Fuson, and Sherin, 2004)

## Appendix E

### North Carolina Integrated Mathematics Project Content Specialist Observation Report

Please fill in the template below and save the file as your last name underscore teacher you observed underscore observation number. For example, smith\_white\_3.doc would be content specialist Mrs. Smith observing Mr. White for the third time. Email final report to [ddoylensp@aol.com](mailto:ddoylensp@aol.com) , [ekrupa@ncsu.edu](mailto:ekrupa@ncsu.edu) , and [helen.compton@gmail.com](mailto:helen.compton@gmail.com) .

**Content Specialist Name:**

**Teacher Observed:**

**School:**

**Date:**

**Class period and length of period:**

**Lesson Taught:**

**Investigation:**

**Topics:**

Content Specialist activities used during this visit (from activities list):

**Offer feedback on class observation.** Prior to a visit or at the beginning of the class, it is helpful for the teacher to email or tell the content specialist about the lesson plan. During the visit the content specialist will be able to observe that lesson and offer feedback to the teacher about the plan, strategies used and successes in the lesson.

**Model teaching.** This may include teaching or co-teaching a lesson during a visit, work with groups as they do an investigation, or leading a small portion of the lesson. The offer of being a model is designed to give the teacher an easy view of some 'how-to's' in a lesson. The teacher must be in a position to observe or jointly participate in the activity and reflect on instruction with the content specialist.

**Provide resources to the teacher.** These resources may include useful articles, handouts, sample test questions or other assessment activities, technology help or suggestions, potential student activities, connections to useful web pages, etc.

**Discuss the content or clarify content.** This discussion may happen before and after lesson or may involve the big picture of a unit or focus on a specific problem.

**Communicate needs of the teacher.** During visits or through other communications, the content specialist may realize that certain materials, a form of technology, or specific classroom resources would make a big difference in the success of the teacher and students. The content specialist will discuss these needs with the teacher and perhaps with the appropriate administrator.

**Suggest strategies for managing groups during collaborative learning.** These strategies may include methods of selecting groups, student roles in groups, issues of accountability, teacher interaction with the group, methods of reporting findings of the groups, and assessment of group activities.

**Develop strategies to manage whole-class discourse.** To offer successful collaborative learning the class will have some whole-class discussions. These discussions may happen with review of last night's homework, in the launch of a lesson, the report of group findings in an investigation, the summary of the mathematics learned, or in other situations. The teacher needs effective strategies for those discussions: what questions to ask, how to document ideas, how to give feedback.

**Keep in touch with the teacher through email or phone conversations.** Since visits are limited to 8 per year, it is important for the teacher and content specialist to be able to collaborate by email or the phone

**Develop collaboration with other STEM teachers.** The teacher can often benefit by working with other teachers in the school or in another STEM school. The content specialist can at times arrange teacher visits to another school.

**Part I: Chronology of period**

Report in ten-minute increments what occurs during the class period. Use the codes provided or a different brief statement about the activities of the class.

Time	Code

Codes

- WU**=warm-up
- R**=review
- HW**=discussion of homework
- LL**=Lesson Launch
- DI**=direction instruction (whole class)
- ID**=interactive development (whole class)
- CL**=collaborative learning
- GR**=group shares with class
- CM**=classroom management
- LT**=lost time
- C**=closure
- O**=other (please specify some description)

**Part II**

Use of Time and Pacing

Based on the chronology of the class period was this, in your opinion, an effective use of time for what the class needed? Rate from 1 (ineffective or inappropriate) to 4 (effective and appropriate)

Is this teacher on pace for the year?

**Instructional Behaviors and Classroom Talk**

How was the class started; did they review or collect homework?

How did the teacher pose the question/investigation for the day?

What type of instructional strategy did the teacher use? List of the approximate percentage of each:

Guide (Collaborative Learning)	Query or Question (Whole Class)	Tell (Whole Class)

Comment:

Was there any closure? Please explain.

Describe the content delivery quality. (Accuracy, Clear, Understanding, Complete) List instructional areas of difficulty.

**Collaborative Learning**

Are they using small groups? \_\_\_\_Yes      \_\_\_\_No

How have the groups been selected? \_\_\_\_Student Choice    \_\_\_\_Teacher Assignment

What criterion was used to create groups?

Describe the collaborative learning?

What was the teacher's role?

How did groups report back to the class?

Other:



**Use of Technology**

What technology was used in class?

None	Calculator	Computers	Other (please specify)

**Comment:**

In your opinion, how effective was the technology use? (1, not effective, to 4, highly effective)?

**Formative Assessment**

What formative assessment methods were used?

None	Procedural Questions	Probing Conceptual Questions	Responses to Student Questions

**Comment:**

Were procedures used to find out how many students were engaged and understanding?

Frequently	Occasionally	Seldom	Never

**Comment:**

Did the teacher recognize when students were lost, un-engaged, or showed evidence of a misunderstanding?

Frequently	Occasionally	Seldom	Never

**Comment:**

### Management Strategies

Over the whole period percent of the class was typically on-task?

90-100%	70-90%	50-70%	<50%

**Comment:**

What strategies did teachers use to respond to the student's off task behaviors?

Were scaffolding techniques used to bring the student back into the flow of instruction?

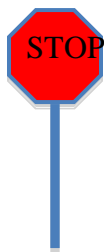
### Other

Any other general observations?

What assistance do teachers need? (materials, content support, management)

What challenges is the teacher having to successfully implement the CORE-Plus curriculum?

**Part III: What you will report to the teacher** (please provide this below)



Before you save, save the file as your last name underscore teacher you observed underscore observation number. For example, smith\_white\_3.doc would be content specialist Mrs. Smith observing Mr. White for the third time. Email final report to [ddoylensp@aol.com](mailto:ddoylensp@aol.com) , [eekrupa@ncsu.edu](mailto:eekrupa@ncsu.edu) , and [helen.compton@gmail.com](mailto:helen.compton@gmail.com) .

Appendix F

**NCIM Project**  
**Core-Plus, Course 1 Table of Contents Record**

**INSTRUCTIONS**

This instrument is designed to document what mathematics content you teach this year from the *Core-Plus, Course 1* textbook. Its design is similar to the format of the Table of Contents of your textbook. That is, it is organized by investigations within lessons within units, with each page displaying the contents of one textbook unit.

We ask that you complete the survey for the first class of the day in which you teach from the *Core-Plus, Course 1* textbook, unless that class is an atypical class (e.g., accelerated, remedial, etc.). For each investigation, select the option that best describes the extent to which the content was taught (if at all) from your textbook: (a) Taught primarily from *Core-Plus* textbook, (b) Taught from *Core-Plus* textbook with some supplementation, (c) Taught primarily from alternative(s) to *Core-Plus*, and (d) Did not teach content.

We ask that you update the survey at the end of each quarter and at that time send us a photocopy of the survey using one of the four postage paid envelopes provided.

Please fill in your name and the school at which you teach:

**Name:** \_\_\_\_\_

**School:** \_\_\_\_\_

Choose the option that best describes the extent to which the mathematics content of each lesson was taught (if at all) from your *Core-Plus, Course 1* textbook.

<b>Unit 1 Patterns of Change</b>		Taught primarily from <i>Core-Plus</i> textbook	Taught from <i>Core-Plus</i> textbook with some supplementation	Taught primarily from alternative(s) to <i>Core-Plus</i>	Did not teach content
<b>Lesson 1 Cause and Effect</b>					
Inv 1	<i>Physics and Business at Five Start Amusement Park</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 2	<i>Taking Chances</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 3	<i>Trying to Get Rick Quick</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Lesson 2 Change Over Time</b>					
Inv 1	<i>Predicting Population Change</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 2	<i>Tracking Change with Spreadsheets</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Lesson 3 Tools for Studying Patterns of Change</b>					
Inv 1	<i>Communicating with Symbols</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 2	<i>Quick Tables, Graphs, and Solutions</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 3	<i>The Shapes of Algebra</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Lesson 4 Looking Back</b>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Choose the option that best describes the extent to which the mathematics content of each lesson was taught (if at all) from your *Core-Plus, Course 1* textbook.

<b>Unit 2</b>		Taught primarily from <i>Core-Plus</i> textbook	Taught from <i>Core-Plus</i> textbook with some supplementation	Taught primarily from alternative(s) to <i>Core-Plus</i>	Did not teach content
<b>Patterns of Data</b>					
<b>Lesson 1 Exploring Distributions</b>					
Inv 1	<i>Shapes and Distributions</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 2	<i>Measures of Center</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Lesson 2 Measuring Variability</b>					
Inv 1	<i>Measuring Position</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 2	<i>Measuring and Displaying Variability: Five-Number Summary &amp; Box Plots</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 3	<i>Identifying Outliers</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 4	<i>Measuring Variability: The Standard Deviation</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 5	<i>Transforming Measurement</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Lesson 3 Looking Back</b>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Choose the option that best describes the extent to which the mathematics content of each lesson was taught (if at all) from your *Core-Plus, Course 1* textbook.

<b>Unit 3</b>		Taught primarily from <i>Core-Plus</i> textbook	Taught from <i>Core-Plus</i> textbook with some supplementation	Taught primarily from alternative(s) to <i>Core-Plus</i>	Did not teach content
<b>Linear Functions</b>					
<b>Lesson 1 Modeling Linear Relationships</b>					
Inv 1	<i>Getting Credit</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 2	<i>Symbolize It</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 3	<i>Fitting Lines</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Lesson 2 Linear Equations and Inequalities</b>					
Inv 1	<i>Who Will Be the Doctor?</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 2	<i>Using Your Head</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 3	<i>Using Your Head...More or Less</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 4	<i>Making Comparisons</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Lesson 3 Equivalent Expressions</b>					
Inv 1	<i>Different, Yet the Same</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 2	<i>The Same, Yet Different</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Lesson 4 Looking Back</b>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Choose the option that best describes the extent to which the mathematics content of each lesson was taught (if at all) from your *Core-Plus, Course 1* textbook.

<b>Unit 4 Vertex-Edge Graphs</b>		Taught primarily from <i>Core-Plus</i> textbook	Taught from <i>Core-Plus</i> textbook with some supplementation	Taught primarily from alternative(s) to <i>Core-Plus</i>	Did not teach content
<b>Lesson 1 Euler Circuits: Finding the Best Path</b>					
Inv 1	<i>Planning Efficient Routes</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 2	<i>Making the Circuit</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 3	<i>Graphs and Matrices</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Lesson 2 Vertex Coloring: Avoiding Conflict</b>					
Inv 1	<i>Building a Model</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 2	<i>Scheduling, Mapmaking, and Algorithms</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Lesson 3 Looking Back</b>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Choose the option that best describes the extent to which the mathematics content of each lesson was taught (if at all) from your *Core-Plus, Course 1* textbook.

<b>Unit 5 Exponential Functions</b>		Taught primarily from <i>Core- Plus</i> textbook	Taught from <i>Core-Plus</i> textbook with some supplementation	Taught primarily from alternative(s) to <i>Core-Plus</i>	Did not teach content
<b>Lesson 1 Exponential Growth</b>					
Inv 1	<i>Counting in Tree Graphs</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 2	<i>Getting Started</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 3	<i>Compound Interest</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 4	<i>Modeling Data Patterns</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 5	<i>Properties of Exponents I</i>				
<b>Lesson 2 Exponential Decay</b>					
Inv 1	<i>More Bounce to the Ounce</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 2	<i>Medicine and Mathematics</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 3	<i>Modeling Decay</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 4	<i>Properties of Exponents II</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 5	<i>Square Roots and Radicals</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Lesson 3 Looking Back</b>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>



Choose the option that best describes the extent to which the mathematics content of each lesson was taught (if at all) from your *Core-Plus, Course 1* textbook.

<b>Unit 6</b>		Taught primarily from <i>Core-Plus</i> textbook	Taught from <i>Core-Plus</i> textbook with some supplementation	Taught primarily from alternative(s) to <i>Core-Plus</i>	Did not teach content
<b>Patterns In Shape</b>					
<b>Lesson 1 Two-Dimensional Shapes</b>					
Inv 1	<i>Shape and Function</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 2	<i>Congruent Shapes</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 3	<i>Reasoning and Shapes</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 4	<i>Getting the Right Angle</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Lesson 2 Polygons and Their Properties</b>					
Inv 1	<i>Patters in Polygons</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 2	<i>The Triangle Connection</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 3	<i>Patterns with Polygons</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Lesson 3 Three-Dimensional Shapes</b>					
Inv 1	<i>Recognizing and Constructing Three-Dimensional Shapes</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 2	<i>Visualizing and Sketching Three-Dimensional Shapes</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 3	<i>Patterns in Polyhedra</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 4	<i>Regular Polyhedra</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Lesson 4 Looking Back</b>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Choose the option that best describes the extent to which the mathematics content of each lesson was taught (if at all) from your *Core-Plus, Course 1* textbook.

<b>Unit 7 Quadratic Functions</b>		Taught primarily from <i>Core- Plus</i> textbook	Taught from <i>Core-Plus</i> textbook with some supplementation	Taught primarily from alternative(s) to <i>Core-Plus</i>	Did not teach content
<b>Lesson 1 Quadratic Patterns</b>					
Inv 1	<i>Pumpkins in Flight</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 2	<i>Golden Gate Quadratics</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 3	<i>Patterns in Tables, Graphs, and Rules</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Lesson 2 Equivalent Quadratic Expressions</b>					
Inv 1	<i>Finding Expressions for Quadratic Patterns</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 2	<i>Reasoning to Equivalent Expressions</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Lesson 3 Solving Quadratic Equations</b>					
Inv 1	<i>Solving <math>ax^2 + c = d</math> and <math>ax^2 + bx = 0</math></i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 2	<i>The Quadratic Formula</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Lesson 4 Looking Back</b>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Choose the option that best describes the extent to which the mathematics content of each lesson was taught (if at all) from your *Core-Plus, Course 1* textbook.

<b>Unit 8</b> <b>Patterns in Chance</b>		Taught primarily from <i>Core-Plus</i> textbook	Taught from <i>Core-Plus</i> textbook with some supplementation	Taught primarily from alternative(s) to <i>Core-Plus</i>	Did not teach content
<b>Lesson 1 Calculating Probabilities</b>					
Inv 1	<i>Probability Distributions</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 2	<i>The Addition Rule</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Lesson 2 Modeling Chance Situations</b>					
Inv 1	<i>When It's a 50-50 Chance</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 2	<i>Simulation Using Random Digits</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 3	<i>Using a Random Number Generator</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 4	<i>Geometric Probability</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Lesson 3</b> <b>Looking Back</b>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Appendix G

**NCIM Project**  
**Core-Plus, Course 2 Table of Contents Record**

**INSTRUCTIONS**

This instrument is designed to document what mathematics content you teach this year from the *Core-Plus, Course 2* textbook. Its design is similar to the format of the Table of Contents of your textbook. That is, it is organized by investigations within lessons within units, with each page displaying the contents of one textbook unit.

We ask that you complete the survey for the first class of the day in which you teach from the *Core-Plus, Course 2* textbook, unless that class is an atypical class (e.g., accelerated, remedial, etc.). For each investigation, select the option that best describes the extent to which the content was taught (if at all) from your textbook: (a) Taught primarily from *Core-Plus* textbook, (b) Taught from *Core-Plus* textbook with some supplementation, (c) Taught primarily from alternative(s) to *Core-Plus*, and (d) Did not teach content.

We ask that you update the survey at the end of each quarter and at that time send us a photocopy of the survey using one of the four postage paid envelopes provided.

Please fill in your name and the school at which you teach:

**Name:** \_\_\_\_\_

**School:** \_\_\_\_\_

Choose the option that best describes the extent to which the mathematics content of each lesson was taught (if at all) from your *Core-Plus, Course 2* textbook.

<b>Unit 1 Functions, Equations, and Systems</b>		Taught primarily from <i>Core- Plus</i> textbook	Taught from <i>Core-Plus</i> textbook with some supplementation	Taught primarily from alternative(s) to <i>Core-Plus</i>	Did not teach content
<b>Lesson 1 <i>Direct and Inverse Variation</i></b>					
Inv 1	<i>On a Roll</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 2	<i>Power Models</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Lesson 2 <i>Multivariable Functions</i></b>					
Inv 1	<i>Combining Direct and Inverse Variation</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 2	<i>Linear Functions and Equations</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Lesson 3 <i>Systems of Linear Equations</i></b>					
Inv 1	<i>Solving with Graphs and Substitution</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 2	<i>Solving by Elimination</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 3	<i>Systems with Zero and Infinitely Many Solutions</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Lesson 4 <i>Looking Back</i></b>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Choose the option that best describes the extent to which the mathematics content of each lesson was taught (if at all) from your *Core-Plus, Course 2* textbook.

<b>Unit 2 Matrix Methods</b>		Taught primarily from <i>Core-Plus</i> textbook	Taught from <i>Core-Plus</i> textbook with some supplementation	Taught primarily from alternative(s) to <i>Core-Plus</i>	Did not teach content
<b>Lesson 1 Constructing, Interpreting, and Operating on Matrices</b>					
Inv 1	<i>There's No Business Like Shoe Business</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 2	<i>Analyzing Matrices</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 3	<i>Combining Matrices</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Lesson 2 Multiplying Matrices</b>					
Inv 1	<i>Brand Switching</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 2	<i>More Matrix Multiplication</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 3	<i>The Power of a Matrix</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Lesson 3 Matrices and Systems of Linear Equations</b>					
Inv 1	<i>Properties of Matrices</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 2	<i>Smart Promotions, Smart Solutions</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 3	<i>Matrices and Systems of Linear Equations</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Lesson 4 Looking Back</b>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Choose the option that best describes the extent to which the mathematics content of each lesson was taught (if at all) from your *Core-Plus, Course 2* textbook.

<b>Unit 3 Coordinate Methods</b>		Taught primarily from <i>Core-Plus</i> textbook	Taught from <i>Core-Plus</i> textbook with some supplementation	Taught primarily from alternative(s) to <i>Core-Plus</i>	Did not teach content
<b>Lesson 1 A Coordinate Model of a Plane</b>					
Inv 1	<i>Representing Geometric Ideas with Coordinates</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 2	<i>Reasoning with Slopes and Lengths</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 3	<i>Representing and Reasoning with Circles</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Lesson 2 Coordinate Models and Transformation</b>					
Inv 1	<i>Modeling Rigid Transformations</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 2	<i>Modeling Size Transformations</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 3	<i>Combining Transformations</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Lesson 3 Transformations, Matrices, and Animation</b>					
Inv 1	<i>Building and Using Rotation Matrices</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 2	<i>Building and Using Size Transformation Matrices</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Lesson 4 Looking Back</b>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Choose the option that best describes the extent to which the mathematics content of each lesson was taught (if at all) from your *Core-Plus, Course 2* textbook.

<b>Unit 4</b>		Taught primarily from <i>Core-Plus</i> textbook	Taught from <i>Core-Plus</i> textbook with some supplementation	Taught primarily from alternative(s) to <i>Core-Plus</i>	Did not teach content
<b>Regression and Correlation</b>					
<b>Lesson 1 Bivariate Relationships</b>					
Inv 1	<i>Rank Correlation</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 2	<i>Shapes of Clouds of Points</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Lesson 2 Least Squares Regression and Correlation</b>					
Inv 1	<i>How Good Is the Fit?</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 2	<i>Behavior of the Regression Line</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 3	<i>How Strong Is the Association</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 4	<i>Association and Causation</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Lesson 3 Looking Back</b>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>



Choose the option that best describes the extent to which the mathematics content of each lesson was taught (if at all) from your *Core-Plus, Course 2* textbook.

<b>Unit 5 Nonlinear Functions &amp; Equations</b>		Taught primarily from <i>Core- Plus</i> textbook	Taught from <i>Core-Plus</i> textbook with some supplementation	Taught primarily from alternative(s) to <i>Core-Plus</i>	Did not teach content
<b>Lesson 1 Quadratic Functions, Expressions, and Equations</b>					
Inv 1	<i>Function and Function Notation</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 2	<i>Designing Parabolas</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 3	<i>Expanding and Factoring</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 4	<i>Solving Quadratic Equations</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Lesson 2 Nonlinear Systems of Equations</b>					
Inv 1	<i>Supply and Demand</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 2	<i>Making More by Charging Less</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Lesson 3 Common Logarithms and Exponential Functions</b>					
Inv 2	<i>How Loud is Too Loud?</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 2	<i>Solving for Exponents</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Lesson 4 Looking Back</b>					
		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Choose the option that best describes the extent to which the mathematics content of each lesson was taught (if at all) from your *Core-Plus, Course 2* textbook.

<b>Unit 6 Network Optimization</b>		Taught primarily from <i>Core-Plus</i> textbook	Taught from <i>Core-Plus</i> textbook with some supplementation	Taught primarily from alternative(s) to <i>Core-Plus</i>	Did not teach content
<b>Lesson 1 <i>Optimum Spanning Networks</i></b>					
Inv 1	<i>Minimum Spanning Trees</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 2	<i>The Traveling Salesperson Problem (TSP)</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 3	<i>Comparing Graph Topics</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Lesson 2 <i>Scheduling Projects Using Critical Paths</i></b>					
Inv 1	<i>Building a Model</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 2	<i>Critical Paths and the Earliest Finish Time</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Lesson 3 <i>Looking Back</i></b>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Choose the option that best describes the extent to which the mathematics content of each lesson was taught (if at all) from your *Core-Plus, Course 2* textbook.

<b>Unit 7 Trigonometric Methods</b>		Taught primarily from <i>Core- Plus</i> textbook	Taught from <i>Core- Plus</i> textbook with some supplementation	Taught primarily from alternative(s) to <i>Core-Plus</i>	Did not teach content
<b>Lesson 1 <i>Trigonometric Functions</i></b>					
Inv 1	<i>Connecting Angle Measures and Linear Measures</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 2	<i>Measuring Without Measuring</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 3	<i>What's the Angle?</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Lesson 2 <i>Using Trigonometry in Any Triangle</i></b>					
Inv 1	<i>The Law of Sines</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 2	<i>The Law of Cosines</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 3	<i>Triangle Models-Two, One, or None?</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Lesson 3 <i>Looking Back</i></b>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Choose the option that best describes the extent to which the mathematics content of each lesson was taught (if at all) from your *Core-Plus, Course 2* textbook.

<b>Unit 8 Probability Distributions</b>		Taught primarily from <i>Core-Plus</i> textbook	Taught from <i>Core-Plus</i> textbook with some supplementation	Taught primarily from alternative(s) to <i>Core-Plus</i>	Did not teach content
<b>Lesson 1 Probability Models</b>					
Inv 1	<i>The Multiplication Rule for Independent Events</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 2	<i>Conditional Probability</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 3	<i>The Multiplication Rule When Events Are Not Independent</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Lesson 2 Expected Value</b>					
Inv 1	<i>What's a Fair Price?</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 2	<i>Expected Value of a Probability Distribution</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Lesson 3 The Waiting-Time Distribution</b>					
Inv 2	<i>Waiting for Doubles</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 2	<i>The Waiting-Time Formula</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Inv 3	<i>Expected Waiting Times</i>				
<b>Lesson 4 Looking Back</b>					
		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

## Appendix H

Last Four Digits of Your Social Security Number: \_\_\_\_\_

### NCIM Content Knowledge Assessment

*Directions: Solve the following problems. Show your work. You may use a calculator. Please turn in the additional graph paper that you use. If you have never **taught** the topic of a problem, indicate so by writing “NT” in the left margin next to the problem.*

1. The City Water Company commission has established water rates as follows: The Water Company charges their customers \$3.75 for the first  $\frac{1}{3}$  gallon of water, and \$.15 for each additional  $\frac{1}{3}$  gallon of water.
  - a. If Darrius used 50 gallons of water in January, how much would his water bill cost?
  - b. If he spent \$39.60 in December, approximately how many gallons of water did Darrius use?
2. At a baseball game, Rory bought 5 bags of peanuts and 3 soft pretzels for \$23.70. At the same game, Leslie bought 2 bags of peanuts and 4 soft pretzels for \$21.10. How much does the combination of 1 bag of peanuts and 1 soft pretzel cost?

3. Simplify the following expression using positive exponents.

$$(-3x^9y^2)^{-2}(5x^{-2}y^4)$$

4. Terrance graphed a quadratic function with zeros at 0 and -4.
  - a. Write a possible equation for Terrance’s function.

- b. Given your equation in part a., identify its domain and range.
- c. What transformations of this equation also go through these two zeros of the function?
5. There is a stream that is 7 feet wide. Jay is standing on one side of the stream. The other side is 5 feet higher than where Jay is standing. Can Jay cross the stream using a 12-foot ladder? Please explain your reasoning.
6. The Aquatics Club is considering selling weekly swimming passes. A market research firm has concluded that the number of weekly passes  $n$  they will sell is related to the price per pass  $p$  in dollars by the formula  $n = -200p + 850$ .
- a. Explain why the income  $I$  from sales of weekly swimming passes can be determined by the formula  $I = -200p^2 + 850p$ .
- b. Will the Aquatics Club always make a profit when selling swimming passes? Explain your reasoning
- c. For what price(s) will the income from weekly swimming passes be \$500? Show your work or explain your reasoning.

7. Three functions  $f(x)$  and their parent functions  $g(x)$  are given below. For each pair of  $g(x)$  and  $f(x)$ , describe the transformations of the graph of  $g(x)$  that result in the graph of  $f(x)$ :

a.  $g(x) = x^2$                        $f(x) = x^2 + 5$

b.  $g(x) = \sqrt{x}$                        $f(x) = \sqrt{x - 4}$

c.  $g(x) = |x|$                        $f(x) = -|2x|$

8. Kenny collected data about a person's average daily caloric intake and their weight in pounds. The least squares regression line and correlation coefficient are given below. Use them to answer the following questions.

x, average daily caloric intake	2000	1567	2342	3450	1247	2876	1430	900
y, weight in pounds.	180	156	182	275	116	231	132	75

$$y = .07x + 25.02$$

$$R^2 = .97$$

- If Mark consumes an average of 1600 calories in a day, about how much would you expect him to weigh?
- Explain what the .07 stand for in the least squares regression line equation?
- Is a linear regression line a good model for this relationship? Explain why or why not.

9. A computer manufacturing company can make a 250-gigabyte (Basic) or 500-gigabyte (Deluxe) hard drive.

Basic hard drive cost \$60 each; each requires 60 minutes to assemble. The basic model can be sold for an \$15 profit.

Deluxe models cost \$85 to make; each requires only 45 minutes to assemble. The deluxe player can be sold for a \$12 profit.

If I have \$800 to invest, and 450 hours of time, how many of each should I make to maximize my profit?