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Investigating Curriculum Use and Its Impact on Teachers and Their Practice

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INVESTIGATING CURRICULUM USE AND ITS IMPACT ON TEACHERS AND THEIR PRACTICE

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ABSTRACT

This study provided insights into how upper elementary teachers from three southern school districts used standards based curriculum materials and the resulting changes in their beliefs, knowledge, and practice. Additionally, this study sought to identify whether the following four factors were predictors of change in teacher practice: coherence of the professional development program, opportunities to collaborate, years of teaching experience, and curriculum use. The participating school districts were selected through purposeful sampling with districts being chosen largely based on a strong commitment to implementing *Eureka Math* in their schools. For comparison purposes, a contrast school district was also included in the study.

This study employed a mixed method sequential explanatory design with data collection occurring in two phases. First, a survey was administered to teacher participants which included Likert-scale items as well as three open-ended questions. After analysis was complete on this data, interviews were conducted with teachers and district leaders in an effort to further explain, clarify, and enhance the data from the survey administration. Analysis involved examining qualitative data for common themes and coding, computing descriptive statistics on the scales from the survey, and conducting a paired sample T-test as well as a stepwise multiple regression. The analyses of both quantitative and qualitative data in this study provided evidence that curriculum materials can serve as a teacher development tool and an agent of change in teacher practice. Analysis of quantitative data revealed that teaching practices shifted significantly as a result of curriculum use and also established coherence and years of teaching experience as predictors of change in teacher practice. Qualitative data supported

these findings and uncovered connections across changes in teacher beliefs, knowledge, and practices. A single, prominent theme emerged across all three areas of teacher change related to problem solving instructional strategies. Curriculum use by teachers appeared to be stable across year one of implementation while in subsequent years, teachers shifted their use of the materials.

CHAPTER 1
INTRODUCTION

Student achievement in mathematics within K-12 education has received an abundance of attention by the federal government in recent years. The United States is increasingly in competition with other countries around the world in mathematics as well as other disciplines such as science, technology, and engineering, collectively referred to as the STEM fields. Currently, there exists an impetus to promote the STEM disciplines in order to increase our competitiveness internationally for the future.

With the passage of the No Child Left Behind Law (2002), high-stakes standardized tests have become the ruler by which we measure our status and progress as a nation regarding student achievement. In this current age of accountability, federal, state, and local authorities which govern education are seeking ways to increase test scores, thereby raising the number of students who are categorized as proficient not only in STEM related fields but all core subject areas. Teachers have been identified as pivotal in determining the level of achievement realized by the students in the classroom. Professional development (PD) for teachers has been recognized as a means to provide teachers with the requisites to make changes to their practice and the potential to improve student achievement (Cohen & Ball, 1999; Cohen & Hill, 2000; Fullan, 2001; Guskey, 2003; Guskey, 2009; Hill, Beisiegel, & Jacob, 2013; Jacob & McGovern, 2015).

Substantial funds have been invested in programs aimed at increasing the knowledge base and pedagogy of teachers, especially in the STEM fields. One example of such investment is the nearly $1.2 billion spent on the “Math-Science Partnerships” funded by the National

Science Foundation (NSF) and U.S. Department of Education between 2002 and 2007 in which pre-service and in-service teachers were provided with mathematics and science learning experiences (Hill, 2011). The Reestablishment of the America Competes Act (2011) provided the continuation of funding for such programs and activities in support of STEM education as did the more recently passed STEM Education Act (2015). An abundance of studies have been carried out in conjunction with these partnerships in an effort to understand the processes associated with teacher professional development. Harris and Sass (2011) indicate that recent studies largely indicate a weak return on the dollars invested in professional development. Jacob and McGovern (2015) suggests that in spite of tremendous amounts of time and money on worthwhile investments in teacher development, we are farther from the goal of knowing how to help teachers improve than has been acknowledged.

Overview of the Literature

For half a century, the path of mathematics education in this country has meandered. Every decade or so, the focus of reform efforts has shifted and many times considerably (Burris, 2005). What has remained consistent is the central role teachers play in communicating mathematics to students. Teachers and how to develop them professionally have been the central topic of many research studies (Smith, Hofer, Gillespie, Solomon, & Rowe, 2003).

Over the past decade, some consensus has been reached on both a causal model for teacher professional development and features associated with the effectiveness of such activities. The causal model consists of teachers participating in professional development which increases their knowledge and skills, leading to changes in their practice which in turn improve student performance. Although content focus, active learning, coherence, collective

participation and duration have been cited by many as key characteristics of effective professional development (Desimone, 2009), some have challenged this finding due to the lack of clear evidence from methodologically rigorous research studies (Hill et al., 2013). Despite the federal government dedicating significant funds to professional development and hundreds of studies addressing the topic of teacher learning and professional development, there is little rigorous evidence available on the impact of professional development on teacher and student outcomes (Garet et al., 2010). Part of the problem is that experimental research is often challenging to carry out in education settings, and this type of research is limited in the literature. There are so many variables which influence what takes place in the classroom, and they can be difficult to control for.

There is still a great deal left to uncover about the development of teachers professionally and its impact on the work they do in the classroom. Understanding how teachers improve their practice is imperative in growing the number of quality teachers in our schools, accomplishing the current goals of school reform efforts, and increasing student achievement. Although there are multiple modes of professional development, including formal, informal, and independent (Desimone, 2009), little is known about how these modes work collectively to influence teacher practice (Jones & Dexter, 2014).

One factor that seems to hold promise in the professional development arena is coherence. Coherence as a characteristic of a professional development program has been defined in a variety of ways. In this study, it refers to how aligned teachers perceive PD activities to be with: the work they do in the classroom; their goals, knowledge, and beliefs as

a teacher of mathematics; and the current mandates on curriculum, mathematics standards, and assessment at the school, district, and state level. Additionally, coherence deals with the degree to which activities are consistent across the professional development experience, forming an integrated program of teacher learning (Garet, Porter, Desimone, Birman & Yoon, 2001). Coherence seems to play a significant role in impacting teacher outcomes and has received increased attention by researchers recently (Allen & Penuel, 2015; Firestone, Mangin, Martinez & Polovsky, 2005; Hochberg & Desimone, 2010; Lindsey, 2010; Penuel, Fishman, Yamaguchi, & Gallagher, 2007). So, how might coherence be translated for education leaders? A special issues brief on creating coherence was recently disseminated by the Center on Great Teachers & Leaders at American Institute for Research. The brief seeks to inform key stakeholders in education such as those at state education agencies about steps which can be taken to align goals of current reform initiatives being implemented concurrently (e.g., Common Core State Standards, teacher evaluation, and professional learning reforms) which are often disconnected from one another (Leo & Coggshall, 2013).

If the planning of professional development programs remains focused on how to achieve the end goal of increased student learning, it is more likely that such experiences will possess the feature of coherence. District and school leaders need to think through the steps which will lead to the increased performance they are seeking. If they want changes in their students, then instructional practice must change. What new learning do teachers need in order to make the necessary changes to their practice and how must their districts and schools support them? Leaders should approach the implementation of all initiatives, whether they originate from the state, district, or local level, with the same focus on the desired end result.

Leaders must reconcile the multiple agendas along with the associated demands placed on teachers, especially in the accountability environment, by addressing these challenges through professional development. Such actions further ensure the presence of coherence in the professional development teacher experience. If leaders will recognize all the avenues by which teachers can develop professionally and consider how these modes can function together for a greater overall effect, the true power of coherence may come to light. Hochberg and Desimone (2010) insist that for professional development to be successful, it must focus on a target that is aligned with standards and assessments and can be achieved using curriculum materials teachers have available to them. A study by McCaffrey et al. (2001) found that professional development for teachers may be more impactful on student achievement when coupled with changes in curriculum that cohere with reform efforts.

Increasingly, there is evidence to support the idea that curriculum materials themselves can be a tool for teacher learning. Studies indicate that teacher learning and change can result from planning and enacting curriculum. In 2005, Remillard conducted an extensive review of the literature on this topic, consolidated the understandings gained from existing relevant studies, and proposed a framework to explain the participatory relationship between the teacher and the curriculum. The teacher and the curriculum both bring their own set of characteristics to the relationship, and the context in which the interaction takes place influences how the planned and enacted curriculum unfold.

When teachers' use of curriculum materials is dissected, especially when it occurs in collaboration with other educators, it becomes apparent that these experiences possess all the features of effective professional development. Such activities are typically focused on content

and involve active learning. Collaboration with colleagues during planning fulfills the collective participation characteristic. Teachers plan for daily lessons the entire school year, so the duration feature is present. Finally, it is difficult to think of an activity that is more coherent with the classroom practice of teachers. Of course, a new curriculum with new instructional practices and possibly even content which is new to some teachers could challenge the existing knowledge and beliefs of some teachers, but as they continue to use the materials, trust in the materials builds and teachers come to understand the curricular vision to a greater degree (Drake & Sherin, 2009).

Context of Current Educational Reform

The current reform effort and implementation of the Common Core State Standards for Mathematics (CCSSM) provides an excellent opportunity to study the participatory relationship between teachers and curriculum. States, districts, and schools around the nation planned and carried out professional development to assist teachers with the transition to the new standards. They scrambled to locate quality curriculum materials that align closely with the CCSSM. For a period of time, there was not much available to educators in the marketplace because there simply had not been enough time for the development of new materials. Then, some found that old materials with a few adjustments were branded as CCSS aligned when in reality very little had changed. The market eventually began to provide more options for educators as time passed.

In 2012, Great Minds, a non-profit education organization located in Washington DC, began development of new curriculum for the state of New York paid for by federal dollars with Race to the Top funds. It was the first and is quite possibly the only PK-12 mathematics

curriculum written from scratch to align with the CCSSM widely available to the education community. Great Minds named their product *Eureka Math* and posted the full curriculum to their website for free download. Its developers consider *Eureka Math* to be educative in nature with professional development built into its modules and daily lessons. A number of third-party organizations have recognized this curriculum above other products on the market for its quality, coherence and close alignment to the CCSSM making it a suitable candidate to be included in research studies targeting curriculum use.

Problem Statement

The causal model for teacher professional development is a logical one, but why are professional development experiences so often failing to produce the intended results? There is evidence that curriculum materials may hold promise as an effective professional development tool. Coherence appears to be a strong factor which influences the success of professional development programs. Little is known about how using the various modes of professional development collectively may influence teacher practice, but such an approach may have potential to impact teacher learning in a powerful way. The existing literature points to the need for further study in each of these areas independently, but the field also lacks study where these areas intersect.

The purpose of this mixed method sequential explanatory study was to understand how the implementation of *Eureka Math* curriculum materials impacted upper elementary teachers from three southern school districts. Additionally, this study sought to identify which of four factors predicted change in teacher practice. The following research questions guided this study:

1. What changes in beliefs, knowledge, and classroom practice do teachers attribute to their use of *Eureka Math* curriculum materials, and is there a statistically significant difference between teacher practices now and practices prior to implementing the curriculum?
2. How does teacher use of curriculum materials develop across multiple years of implementation?
3. What factors (i.e., curriculum use, opportunities to collaborate, coherence in the PD program, and number of years teaching) predict change in teacher practice?

Significance of the Study and Rationale

With so little rigorous evidence of professional development impacting student outcomes in the scholarly literature (Garet et al., 2010) and recent studies largely indicating a weak return on the dollars invested in professional development (Harris & Sass, 2011; Jacob & McGovern, 2013), the education community is left with many unanswered questions about how to use professional development to achieve improved student outcomes. It is important to improve our understanding of how teacher learning proceeds and why learning results in changed behavior (McDonald, 2012) if we are to be effective in using professional development as a means to cultivate change in instructional practices and ultimately in student performance. McGee, Wang, and Polly (2013) state that

> The direct relationship between teaching learning, learning through PD, and teacher practice is yet relatively unexamined. How teachers are able to translate their new learning into classroom experiences for their students is important to the goal of education itself to increase student learning. Another important factor to be considered is the teacher's own learning process and how certain points in that process should be examined in order to create a more harmonistic experience for the teacher during implementation of their learning (p. 25).

Although positive results on the use of curriculum materials as a form of professional development are encouraging, many questions remain about their use (Frykhom, 2005). Research which focuses on the role of reform-based curriculum materials in the teacher change process is increasing. Studies on the topic investigate both the challenges teachers face in using novel text resources and also the potential they hold for supporting teachers in their efforts to grow professionally and improve their practice (as cited by Spielman & Lloyd, 2005). Thanks to this foundational research, we have some information about how a limited number of teachers use and learn from a small number of educative curriculum materials. Continued exploration by researchers of the ways in which educative curriculum materials can support teacher learning is needed in order to develop "understanding of a form of professional development that holds promise for being both effective and efficient—if thoughtfully and carefully designed" (Davis & Krajcik, 2005, p. 10).

Furthermore, the change that results through the process of using innovative curriculum materials may be more likely to endure because the changes are self-directed in nature. The examination of the shifts in teacher beliefs as they learn mathematics while using these types of resources can provide meaningful contributions to those charged with developing teachers professionally (Spielman & Lloyd, 2005). The use of such materials as a means of providing professional development for teachers has appeal due to its scalability and its coherence with teacher practice (Collopy, 2003).

Eureka Math

The mission of Great Minds, the developer of *Eureka Math*, is "to ensure that all students, regardless of their circumstance, receive a content-rich education in the full range of

the liberal arts and sciences, including English, mathematics, history, the arts, science, and foreign languages". Great Minds has worked with educators and scholars to develop instructional materials and conduct research in a variety of content areas. Furthermore, the non-profit promotes policies "that support a comprehensive and high-quality education in America's public schools" (“Mission Statement”, 2015, para. 1). The paragraphs which follow contain information on the history of *Eureka Math* as well as details on its structure and design, the philosophy of its developers, and evaluation results by third-party reviewers.

History of *Eureka Math*

Great Minds was awarded four contracts by the New York State Education Department (NYSED) to produce mathematics curriculum materials aligned to the Common Core Learning Standards, New York State's version of the Common Core State Standards. These four contracts spanned from PreKindergarten to Grade 12 and were funded by Race to the Top funds awarded to NYSED by the federal government. The project was led by Project Director Nell McAnelly, and Scott Baldridge served as the lead mathematician on the project, both from Louisiana State University. The development of the curriculum started in the spring of 2012 and was completed in December of 2014.

An extensive review process, including mathematicians who played a role in authoring the new standards, the progression documents and the Publisher's Criteria ensured accurate interpretation of and appropriate alignment to the standards. The development process was undertaken primarily by teacher writers under the advisement of lead writers and mathematicians. The completed curriculum totaled more than 45,000 pages. As materials were developed, NYSED posted the materials on their website, www.engageny.org, not only for

ease of access by their own teachers, but teachers around the nation. They hoped their investment would benefit educators far beyond the borders of their state. The materials developed for the state of New York became the foundation for *Eureka Math*, the name given to the comprehensive mathematics curriculum and professional development platform by Great Minds. In line with the philosophy of the non-profit, Great Minds has posted the entire curriculum on their website, www.greatminds.org, for free download. In addition, they have continued to improve upon their original product through updates and the creation of supplemental resources and products to assist schools with implementation.

Curriculum Coherence and Design

A coherent curriculum. *Eureka Math*, using the CCSSM as its foundation, presents itself as a coherent curriculum which tells the story of mathematics. The curriculum organizes the mathematical progressions into carefully sequenced and crafted instructional modules. The elementary portion of the curriculum is known as *A Story of Units*, followed by *A Story of Ratios* in middle school, and high school's *A Story of Functions.* This approach was instrumental in achieving the coherent nature of the materials which curriculum writers aimed for during the development process. The logical flow of mathematical concepts within and across grades is a key advantage of this curriculum. Close attention was given to avoiding gaps in content as well as needless repetition. The completion of each module arms students with the knowledge needed to take on the increasingly challenging concepts presented in the next.

The coherence of the elementary level of *Eureka Math* is built upon the unit, the story's main character and the basic building block of arithmetic. As new concepts are introduced, students learn how to transfer their knowledge about unit-based procedures and broaden their

existing understanding. When students enter school they come to understand one object as one unit, such as a turtle is one unit. Students learn to relate numbers to each other and to 5 and 10. They begin to recognize numbers as units which can be manipulated. Numbers can be broken apart, formed and related to one another. As students move on to more complex concepts, the idea of the unit remains transferable.

> *A Story of Units* investigates how concepts like place value, algorithms, fractions, measurements, area, etc. can all be profitably understood in the context of relating, converting between, and manipulating types of units (e.g., inches, square meters, tens, fifths). For example, quantities expressed in the same units can be added: 3 apples plus 4 apples is 7 apples. Likewise, 3 fifths plus 4 fifths is 7 fifths. Whole number multiplication, as in "3 fives = 15 ones," is just another form of converting between different units, like when we state that "1 foot = 12 inches". These similarities between concepts drives the day-to-day theme throughout the PK-5 curriculum: each type of unit is manipulated just like every other type of unit through the common features that all units share. Understanding the common features in turn makes it much easier to sharply contrast the differences. Adherence to the theme helps students to no longer think of every new topic they study as completely separate from the previous topics studied (Great Minds, 2015, Foreword).

Another way *Eureka Math* strives to achieve coherence is the use of a finite set of concrete and pictorial models. With continued exposure, the idea is that students develop increased familiarity and skill with the models to assist in building the necessary connections between mathematical topics. Continued use across grade levels facilitates more rapid acquisition of new concepts. But the models themselves are simply tools and require instructional strategies to implement in the classroom. For a given model, there is typically a collection of strategies for its use through the grades which correspond to the natural progression of a concept. These strategies support the implementation of the models and are embedded within the curriculum. Figure 1 provides a summary of the models and the primary application area for each.

Numbers Through 10	Place Value and Standard Algorithms	Fractions
▪ Number Towers ▪ Number Path ▪ Number Bond	▪ Bundles ▪ Place Value Chart ▪ Base-Ten Blocks ▪ Money ▪ Number Disks (with Place Value Chart)	▪ Number Line ▪ Area Model
Addition and Subtraction	**Multiplication**	**Word Problems**
▪ Ten-Frame	▪ Array and Area Model ▪ Rekenrek	▪ Tape Diagram

Figure 1. Models Included in Eureka Math by Application Area

Curriculum design. Although the lesson structure in *A Story of Units* (PK-5) differs considerably from those in *A Story of Ratios* (6-8) and *A Story of Functions* (9-12), they do share common design features at the module and topic levels. Because this study primarily focuses on grades at the elementary level, the description of module and lesson design is restricted to *A Story of Units*. See Appendix A for information on module design.

The structure of the lessons in *A Story of Units* highlights the shift of rigor called for by the standards. The lesson components include Fluency Practice, Concept Development, Application Problem, and Student Debrief, and the time devoted to each of these four components varies depending upon the standards the lesson is addressing. Lessons typically begin with fluency and allow students an opportunity to practice previously learned skills or to anticipate future concepts. Fluency exercises are generally fast-paced, energetic, and encourage students to recognize and celebrate their improvement. The mastery of lower-level skills is key in order for students to be able to focus on solving higher-level problems without using up valuable attention resources on the basic computational parts of problems.

Concept Development often follows the fluency component of the lesson and typically presents the progression of the content from concrete to pictorial to abstract. This structure supports an increasingly complex understanding of concepts. There are exceptions to this presentation of simple to complex. Students' understanding of a given concept at a particular time determines the starting point. Concrete is most beneficial when students have a weak understanding conceptually. The Concept Development details sample dialogue between teacher and students and are not meant to be scripts that teachers read word for word to students. The expectation is that a teacher's word choice will be different from the vignettes and suited to his/her specific students, that they will be used to help anticipate how students might respond when given certain prompts. The sample exchanges help outline for teachers the type of thinking and interaction they could expect to see in association with achieving a particular objective.

The Application Problem component of the lesson is a place for applying mathematical concepts from the Concept Development to real-world problems. This component presents problems which are meant to cause students to think critically and creatively. A slower pace and tone are evident here when contrasted with Fluency Practice, with students applying systematic approaches to solving these types of problems. Once students get comfortable with a particular approach, they are able to internalize the behaviors and thought processes and less guidance is needed, allowing students to work more independently.

The Student Debrief models how a teacher might close the lesson and provides time for reflection and consolidation of understanding. It is a time when students can make connections on their own and provides opportunity for further engagement in the Mathematical Practices.

The questions or bullet points supplied in the debrief assist the teacher in planning for higher-order thinking questions that are right for his/her students, and sharing high-quality work is a consistent feature of the Student Debrief. Exit Tickets conclude this component of the lesson in order to formatively assess student learning for the day (Great Minds, 2015).

Evaluation Results of *Eureka Math* Materials

To date, *Eureka Math* is the only mathematics curriculum developed from scratch to align to the new standards. *Eureka Math* has received superior reviews by numerous organizations. In a review released in March of 2015 by EdReports.org, a non-profit organization evaluating textbooks and curricula with claims of alignment to the CCSSM, *Eureka Math* stood out from twenty series reviewed by meeting criteria for alignment to the standards at all grades evaluated, K-8. Another noteworthy review and endorsement came from the Louisiana Department of Education (LDOE). *Eureka Math* was recognized by LDOE as a tier 1 curriculum for Grades K-11 receiving the best possible score for indicators of superior quality. Achieve also acknowledged multiple lessons from *Eureka Math* as curriculum exemplars through their EQuIP evaluation process.

Curriculum Developer Philosophy

Great Minds is not a typical textbook publishing company. Feedback from the field is often used in decisions making around upcoming projects and has shaped product offerings. For example, responses obtained during a recent listening tour resulted in the creation of a new supplemental product which supports parents in assisting their students with homework. The vision which drives the company has created a unique approach to curriculum development and professional development delivery.

Although *Eureka Math* is an extensive and thoroughly developed resource for teachers, its developers' intent is not that it be prescriptive. Great Minds believes teachers play a central role in constructing experiences for the students they teach in their unique context and offers *Eureka Math* as a basis for honing their craft. The depth of this perspective is evident through their professional development offerings which include a session on *Customization and Preparation of Eureka Math Lessons* focusing on getting teachers familiar with how to customize lessons to meet the needs of their own students.

Locating the Researcher in the Study

As a teacher of mathematics for thirteen years, a high school instructional coach and an administrator over curriculum and instruction, I have a long history in the field of education. I have always had a passion for improving mathematics education and a special interest in teacher preparation and development. I was provided the opportunity to join Great Minds in 2012 and play a role in managing the development of what would come to be known as *Eureka Math*. My excitement in being a part of providing teachers with much needed materials for implementation of the CCSSM came from experiences in my own school district in South Louisiana as we struggled to piece together a mathematics curriculum for our teachers aligned to the new standards in a very short timeframe.

As districts around the country have begun to implement *Eureka Math*, anecdotal reports have been rolling in from teachers, schools, and districts about the impact the materials are having on teachers and their students. Not every implementation is a huge success story as many challenges and struggles often accompany this type of change. Standardized test data has begun to surface demonstrating impact on student performance as well.

I continue to work for Great Minds today. My position with the company is what has spurred my interest in studying the role curriculum materials play in the professional development arena. My background in education along with my role in curriculum development offers a unique and informed perspective in this study.

CHAPTER 2
LITERATURE REVIEW

Brief History on Math Education

A critical point in the history of mathematics education came with the Soviet Union's launching of Sputnik 1. This event signified the beginning of the race to space, and the United States' concern that it was lagging behind in the areas of math and science sparked reform efforts at a national level. The "New Math" movement of the 60s and 70s was birthed from these reforms which focused on language and properties, proof, and abstraction. This movement was thought by some to bring about more confusion than clarity, and soon the pendulum swung in the direction of "Back to Basics" in the late 70s and early 80s with an emphasis on computation and rote memorization of algorithms and facts (Burris, 2005).

Yet another shift occurred in the late 80s with a focus on critical thinking. In 1989, the National Council of Teacher of Mathematics (NCTM) Standards were published which stressed problem solving, communication, connections and reasoning. NCTM also released Professional Standards for Teaching Mathematics in 1991 followed by Assessment Standards for Teaching Mathematics in 1995. An update on the standards was done in 2000 by NCTM with the Principles and Standards for School Mathematics. This release detailed the standards and expectations for grade levels from PK-12 in each of five content strands: number and operations, algebra, geometry, measurement, and data analysis and probability. Five process standards were also outlined which are related to the methods used to acquire content knowledge: problem solving, reasoning and proof, communication, connections, and representation (Burris, 2005).

Legislation to support education reform efforts such as the Goals 2000 Educate America Act (1994) and the No Child Left Behind Act of 2001 (2002) mandated systems be implemented by states to hold teachers and schools accountable for educating all students. These laws led to the creation of content standards, performance standards and assessment measures by nearly every state in order to comply, and the influence of the NCTM standards were evident in state frameworks produced. In some cases, local school districts developed their own standards and were typically based on the state model or NCTM standards (Burris, 2005).

With states using their own processes for developing and implementing standards, it is not hard to understand how the result would be sets of standards and expectations for students which varied widely across the nation. Under NCLB, states may have lacked motivation to make their standards and assessment measures too rigorous for fear they would look bad in comparison to other states. The initiative which resulted in the release of the Common Core State Standards in 2010 sought to remedy these issues and ensure that students, no matter where they were educated, were prepared to enter postsecondary education or the workforce upon graduation from high school. The initiative sponsored by the National Governors Association and the Council of Chief State School Officers aimed to raise the quality of education and achieve greater consistency nationally.

The instructional shifts called for by the Common Core State Standards for Mathematics (CCSSM) include focus, coherence and rigor. Focus refers to limiting the scope of content at each grade level, so the breadth of what students learn is narrowed allowing for experiences of greater depth and the potential for increased mastery. Coherence is about students being able to connect the mathematics they learn within a grade and across grades. The idea is for

students to be able to link the concepts together and not think of mathematics as a discrete set of disconnected topics. Rigor is called for by the standards and refers to a balance of procedural fluency, conceptual understanding and application to the real world.

The CCSSM lay out the content by domain students should learn at each grade level from K-8 and the mathematics high school students should learn as well. The standards do not prescribe the order of topics or particular pedagogy to be used during instruction, but they do call out critical areas of focus for grades K-8 and describe possible pathways for covering high school content. There are eight Standards for Mathematical Practice which are to be taught in connection with the content standards at every grade level from K-12. How this is achieved is left to implementers at the local level.

Forty-four states and the District of Columbia became members of the CCSS Initiative initially, but since that time several have voted to repeal or replace the standards due to political controversy which ensued upon adoption or implementation. Computer-based assessments were created by two different consortiums, Partnership for Assessment of Readiness for College and Careers (PARCC) and the Smarter Balanced Assessment Consortium. While many states were set to begin testing during the 2014-15 school year, some have withdrawn from these consortium tests. Even with the controversy surrounding the CCSS, the nation is on more coherent ground in terms of the set of skills it expects students to be proficient in than possibly it has ever been before.

Teacher Professional Development Research

History of Teacher Professional Development Research

What has remained constant in this seemingly ever-changing realm of math education is the instrumental role teachers play. Increasingly research has focused on how to develop teachers professionally for greater impact on student performance. Research in teacher education over the past 40 years has centered on uncovering various perspectives on both what spurs good teaching and how to shape effective professional development (Smith et al., 2003). Prior to the 1950s, professional development for teachers was sparse due to the belief that additional development was not necessary after teachers finished their initial preparation. Early teacher professional development focused on the communication of ideas and information without much thought given to the process of teacher learning and the significance of contextual factors (McDonald, 2012). In the 1960s and 1970s, research in teacher education and professional development focused on teacher behaviors and how professional development might change them. Since then and up until the 1990s, this area of research meandered from school improvement to student achievement to teacher quality (Smith et al., 2003). Over the last decade, a shift has been made to developing a consensus on a causal model for professional development as well as effective professional development design.

Consensus in Teacher Professional Development Research

Consensus on a casual model for teacher PD. According to Desimone (2009), there are a variety of contexts for teacher learning including group-oriented and independent as well as formal and informal. Proposed amendments to Section 9101 (34) of the Elementary and Secondary Education Act as reauthorized by the NCLB Law of 2001 define the term professional

development as “a comprehensive, sustained, and intensive approach to improving teachers’ and principals’ effectiveness in raising student achievement”. Today, there are many PD opportunities offered to teachers through their schools, districts, local universities, and departments of education, which are typically of a structured nature and aim to achieve explicit outcomes. The scholarly literature contains valuable information which can be beneficial to professional development providers in designing such efforts to optimize effectiveness and productivity.

A consensus on the effects of teacher professional development has emerged and consists of teachers experiencing effective professional development followed by an increase in teacher knowledge and skills and/or changing their attitudes and beliefs. Teachers then use such changes to improve the content of or approach to their instruction, and student learning is fostered (Desimone, 2009). This process is illustrated in Figure 2 below. Although the process

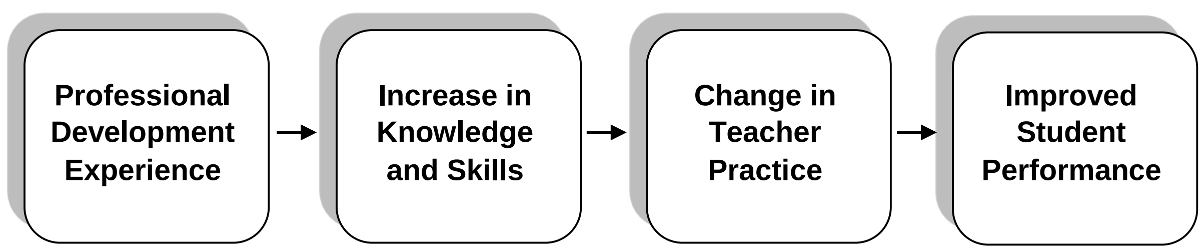

Figure 2. Causal Model for Teacher Professional Development

of professional development leading to student achievement is not always stated in the same number of steps or stages, a similar rationale seems to be followed generally. Yoon, Duncan, Lee, Scarloss, and Shapley (2007) describe professional development affecting student achievement through three steps. “First, professional development enhances teacher knowledge and skills. Second, better knowledge and skills improve classroom teaching. Third,

improved teaching raises student achievement" (p. 4). Borko (2004) cites numerous studies (Fennema et al., 1996; Franke, Carpenter, Levi & Fennema., 2001; Knapp & Peterson, 1995) which indicate that the learning process for teachers can be lengthy and inexact and that some teachers change more than others during participation in the same professional development. Borko also states that some elements of teachers' knowledge and practice are more readily altered than others.

A consensus on features of effective PD. Desimone's 2009 study of the literature yielded a consensus on several characteristics of PD related to increases in teacher knowledge and skills and improvement in teacher practice. Based on this, the following five features of effective professional development have been suggested:

1. Content focus. The subject matter content and how students learn that content should be a core part of PD for teachers (Garet et al., 2001).
2. Active learning. As opposed to passive learning (e.g., lectures), teachers undergoing PD should be involved in the learning process. This can include activities such as observing expert teachers, being observed and engaging in discussion and feedback, collaborating with other teachers on a specific task, producing written work on a difficult idea or problem, etc. (Desimone, 2009).
3. Coherence. The PD should be consistent with the work teachers do in the classroom, with the teacher's knowledge and beliefs, and with school, district, and state standards, curriculum frameworks, and assessments. Activities should be consistent across the PD experience, forming of an integrated program of teacher learning (Garet et al., 2001).

4. Duration. PD should be of sufficient length. Current research suggests the tipping point may be over a semester and at least 20 hours of contact time (Desimone, 2009).
5. Collective participation. PD should include opportunities for interaction and discussion among participants. This may be prompted through participation of teachers from the same school, department, discipline, or grade (Desimone, 2009; Garet et al., 2001).

Desimone (2009) states that these fundamental features of PD are essential for the effectiveness of professional development and therefore good targets for evaluation. She suggests their inclusion in impact studies as a "next step to understanding the relative importance of the features for improving student achievement in different contexts" (p. 183). To emphasize the degree to which such PD features have been accepted as keys to effectiveness, one needs only look to a publication disseminated by The American Educational Research Association (AERA) in 2005. This document puts forward a model for PD that incorporates all five of the features discussed above which show, to varying degrees, influence on change in educators' knowledge, skills, and instructional practice (Holland & AERA, 2005).

Even when quality PD is delivered, it does not guarantee that an increase in student performance will result. If one link in the PD model is weak or missing, an improvement in student achievement cannot be expected. For instance, if a teacher fails to apply new ideas, information or knowledge from professional development to their classroom instruction, students will not profit from the teacher's professional development (Yoon et al., 2007). The realities teachers face in the classroom can sometimes create challenges for the transfer of such training to their instructional practice. A clearer understanding of the factors which influence the transfer of learning from PD is necessary. Ingvarson, Beavis, Bishop, Peck, and

Elsworthet (2004) point out the wide range of factors which influence classroom practice in their survey study involving 3,250 teachers. Among these are teacher, student, school, and system level factors. Such factors influence a teacher's decision making and impact the degree to which teachers transfer their knowledge and skills gained during professional development to their instruction.

Transfer of Teacher Learning

Whether teachers experience professional development through a more formal, organized experience or through informal or independent modes, the widely agreed upon casual model for teacher PD indicates that a change must occur in the teacher and in his or her practice in order for impact on student achievement to occur. In spite of the limited amount of research, it has been acknowledged that a variety of factors impact or are related to the transfer of teacher learning. Over the years, numerous instructional models of transfer have emerged related to professional development, and some of the factors highlighted include characteristics of the teachers, their schools, the PD program and facilitators. Other considerations noted in these models are the germaneness of the material to the learner, the provision of ongoing support and the interaction of task variables with teacher characteristics (McDonald, 2012).

One perspective reflected in early research on the topic of learning transfer suggests that teachers may embrace a new idea or practice, but they may or may not adopt it. In 1977, Doyle and Ponder's (as cited by Smith et al., 2003) qualitative study found that teachers make decisions about whether to implement based on instrumentality, congruence, and cost. Instrumentality refers to the quality of the description and presentation of the new

practice. Congruence relates to the coherence between the new practices and the teacher's existing philosophy and practice. Cost denotes the benefits associated with implementing the new practice versus the time and energy required to do so.

Model of teacher change. Just because teachers try out a new instructional strategy or implement new content does not necessarily ensure that the change will be a permanent one. This is the first step, but is not a guarantee of true long-term change in teacher practice. Guskey (2002) put forth a model for the process of teacher change which places emphasis on the successful implementation of new teacher practices rather than the professional development experience itself. According to his model, it is the evidence that a newly instituted practice has led to improvement in student learning outcomes that shapes a teacher's attitude or belief in a significant way. This theory stresses the power that enacting planned curriculum may hold in shaping teachers professionally. A teacher must be influenced enough by the professional development experience itself to alter instruction, but Guskey suggests that real change does not take place until implementation occurs with positive reinforcing results from student performance. This process is not always a linear one but can be rather cyclical in nature and may not always be free from challenges. A case study by Huberman in 1981 (as cited by Guskey, 2002) of a district's efforts to implement a new reading program revealed the high anxiety and confusion teachers can experience during the initial stages of implementation.

McGee et al.'s (2013) study used Guskey's model as a framework to investigate the way teachers perceived the impact of professional development, their perceptions on teaching and learning mathematics, and how they transferred their PD experiences into practice. Twenty-

three participants of an intensive PD program centered on the implementation of a standards-based mathematics curriculum were interviewed and observed. Teacher participants described their learning of mathematics content and expressed that their comfort level with the curriculum and standards-based instructional approaches grew over the course of the project. Participants also stated their concerns around standardized state testing which acted as a barrier to transferring PD experiences into their practice.

The influence of the school environment. Work environment can impact the transfer of learning expected with professional development opportunities. Poor school culture can impede teacher change. A study by Joyce suggests a single withdrawn teacher holding just informal power and influence within a school can hinder any type of collective action or change from taking place (as cited by Smith et al., 2003). In fact, pressure from teachers' colleagues can be more influential than educational considerations. Visiting other classrooms and discussing those observations with peers has been shown to assist teachers in changing their belief system (Pehkohen & Torner, 1999). Johnson (2006) found in a case study involving eight participants focused on collaborative, sustained, whole-school PD at two middle schools that the lack of administrative support and buy-in served as hindrances to the transfer process.

PD Research Challenges and Possible Paths Forward

Paucity of rigorous research on the effects of teacher PD. Guskey (2009) points to the knowledge gap which exists between what we believe about the features of effective professional development and what we actually have evidence to validate. He references the lack of methodically rigorous studies which confirm the effectiveness of professional development when it is defined by its ability to impact student outcomes positively.

Although the federal government has dedicated significant funds to PD and hundreds of studies have addressed the topic of teacher learning and PD, there is little rigorous evidence available which confirms the impact of PD on teacher and student outcomes (Garet et al., 2010). While randomized controlled experiments are the preferred choice by the U.S. Department of Education Institute of Education Sciences' (IES) What Works Clearinghouse (WWC) for educational research studies, such expectations are not often a viable option in the evaluation of educational programs (Yoon et al., 2007). Experimental and quasi-experimental designs are considered the most rigorous, but are often not possible in actual field settings (Gaytan & McEwen, 2010). Most educational programs are executed in the field where complex conditions exist, including a wide range of possible moderating and mediating variables. Independent variables can rarely be manipulated by researchers in evaluation settings in education and a single, discrete treatment is not generally identifiable (Chatterji, 2005). In a study sponsored by the IES, of the more than 1300 studies identified as potentially addressing the effect of professional development on student achievement in three content areas including mathematics, only nine met the WWC evidence standards. All nine of the studies focused on PD effects on elementary school student achievement (Yoon et al., 2007).

Discouraging results raise questions about what we know. More recently the consensus reached on design elements of effective PD has been questioned by Hill et al. (2013) who claim that the field of professional development has arrived at a crossroad. They suggest that the purported consensus reached on program design elements thought to maximize teacher learning has been turned on its head by discouraging outcomes from recent rigorous studies of professional development programs possessing some or all of these

features. Furthermore, recent econometric studies largely indicate a weak return on the dollars invested in professional development (Harris & Sass, 2011). Although it is too soon to understand what the reasons are for such results, there are many possibilities. Some examples include ineffective program content, poor research design (i.e., insufficient power, inadequate measures, etc.), scaling problems and inadequate implementation of PD best practices (Hill et al., 2013).

Although evidence is lacking, Guskey (2009) emphasizes that professional development remains key to enhancing the knowledge and skills of educators and improving student learning. Jacob and McGovern (2015) also remain confident in the potential of professional development to improve teachers as well as student learning despite study results that question our understanding of how this occurs. They surveyed more than 10,000 teachers and 500 school leaders across three large public school districts and a midsize charter school network and interviewed over 100 participants in teacher development. Using a broad definition of professional development, they used multiple measures of performance to pinpoint teachers who improved substantially and then sought to identify mutual experiences or attributes among the group. They were disappointed with their findings which challenged many of their assumptions. The conclusion drawn was that "the evidence base for what actually helps teachers improve is very thin", and "the widely held perception among education leaders that we already know how to help teachers improve (p.ii)" is a mirage.

A call for improvement of outcome measures. This lack of clear evidence raises the question about the adequacy of existing as well as specially designed instruments to detect the full effects of PD on classroom practice and student learning. The National Science

Foundation's Math and Science Partnership (MSP) Program brings together about 150 institutions of higher education with over 450 K-12 school districts and a multitude of stakeholders. The competitive, merit-based grants awarded to these partnerships are a response to the growing concern around U.S. children's academic performance in mathematics and science. A study by Moyer-Packenham, Bolyard, Oh, and Cerar (2011) analyzed a cross-section sample of over 2000 professional development activities provided to teachers through MSPs involving over 34,000 teachers. The study found that there were few measures employed by the MSP programs to assess the PD activities. Overall, PD assessments were not found to be well-connected with classroom practice and student outcomes which highlights the need for better methods of verifying results.

Moyer-Packenham and Westenskow (2012) focused on how MSPs create processes for assessing teachers' content knowledge growth when they include such measures in their evaluations. The most common means of measuring such growth were pre- and post-tests, but the instruments used varied widely, and some partnership programs did not measure growth in content knowledge at all. The authors suggest the possible need for major funding contributors to PD programs such as the NSF and the Department of Education to request common processes for measuring growth from participating partnerships. This would facilitate the comparison of results across programs and studies and allow for accumulation of evidence.

A common core of teaching practice. Ball and Forzani (2011) suggest more than just common processes for measuring growth. They point to the need for a common core of teaching practice which "would include explicit learning goals that encompass the range of skills, knowledge, understandings, orientations, and commitments that underlie responsible

teaching "(p. 38). Other professions decompose practice and agree on markers such as collective knowledge, shared standards for practice, and common principles and protocols along with processes to develop, support, and assess them. With the arrival of the Common Core State Standards (CCSS), Ball and Forzani believe it is time for teaching to "identify specific instructional practices, and specific topics and texts within school subject areas, that could serve as the foci of a redesigned professional curriculum for learning to teach responsibly" (p. 38) across all types of programs and pathways. They point to the CCSS as a source from which to derive the content.

On a similar note, Wu, a mathematician and PD provider, asserts that all teachers must be provided with a body of mathematical knowledge that satisfies two main conditions. The first is that it is relevant to the mathematics they are teaching in their classrooms. The second condition is that is aligned with specific fundamental principles of mathematics of which all teachers should be aware (2011).

Coherence in Teacher Professional Development

Modes of professional development. Although there has been a great deal of focus on formal PD in research studies, the literature summarizes the primary modes of professional development in which teacher learning occurs as formal professional development, informal teacher learning, and independent learning (Desimone, 2009; Jones & Dexter, 2014). More and more research is accumulating on the potential held by informal teacher learning and independent learning and using the various modes of PD in combination for greater impact. A recent study aimed to extend the emergent literature on how to employ these three modes of learning, particularly when supported by technology, for a more substantial effect on teacher

learning. The authors suggest a more holistic approach to teacher learning and claim that opportunities will be missed to enrich teacher and student outcomes “by not supporting, recognizing, connecting to, and building upon teachers’ informal and independent learning processes already in place” (Jones & Dexter, 2014, p.383). Desimone (2009) points to the difficulty in sorting out the impact of specific teacher learning activities in studies given the complexity and interrelatedness of opportunities to develop professionally.

The importance of coherence. Coherence is one of the five features of effective professional development identified by Desimone (2009) and others (Jeanpierre, Oberhauser, & Freeman, 2005; Johnson, Kahle, & Fargo, 2007; Penuel et al., 2007). According to Garet et al.’s (2001) study, content focus, active learning, and coherence contribute to teacher enhanced knowledge and skills, exerting a positive influence on teacher practice. Coherence and content focus are the two core features which have been shown to have the most positive influence on both enhanced knowledge and skills and change in teacher practice, with coherence being the most influential.

Coherence as a characteristic of a professional development program has been defined in somewhat different ways, but generally refers to the cohesiveness of the program and how aligned teachers perceive activities to be with their own classroom practice, their instructional knowledge and beliefs as teachers, and the current mandates on curriculum, math standards, and assessment at the school, district, and state level (Garet et al., 2001). Penuel et al. (2009) defines coherence as “teachers’ interpretations of how well-aligned the professional development activities are with their own goals for learning and their goals for students” (p. 418). Firestone, et al. (2005) suggests that coherent professional development, in general,

concentrates on fewer areas at a deeper level with effective follow up and includes at least three elements: consistency of focus, extended learning opportunities that are subject specific, and experiences which model instructional approaches teachers are expected to use in the classroom. This perspective of coherence focuses on the internal consistency of the PD program rather than its alignment with external elements associated with teacher practice. Their study of three urban school systems where district offices structured professional development programs for their teachers identified the district with the most coherent focus on aiding teachers in the development of deep content knowledge as having the greatest teacher-reported impact on classroom practice. The findings of another study which surveyed 454 teachers in an inquiry science PD program suggested teachers' perceptions about the coherence of their PD experiences was a significant positive predictor for teacher change (Penuel et al., 2007).

Demands on teachers come from a variety of sources and are sometimes conflicting, leaving teachers feeling like they are being pulled in multiple directions at once (Quiroz & Secada, 2003). Reconciling the demands from multiple agendas (e.g., teacher evaluation, new standards, curriculum mandates, state standardized testing, etc.), especially in the accountability environment, is often a challenge and should be addressed through professional development (Hochberg & Desimone, 2010). Each teacher brings his or her own interpretive frame to the PD experience and, therefore, filters the PD content and messages differently, attempting to fit new information into their existing schema (Firestone et al., 2005). How well a teacher is able to assimilate these experiences has a great deal to do with how coherent they perceive the PD. "To be successful, professional development that is part of the accountability

system must be coherent and must focus teachers on a target that is aligned with standards and assessments and that can be achieved using the curriculum materials at hand" (Hochberg & Desimone, 2010, p. 93). Professional development must function as a vehicle for reform initiatives while also helping teachers advance towards the ultimate goal of increased student learning.

The purpose of one study (Lindsey, 2010) was to determine the extent of the coherence of professional development designed by K-12 public schools targeting student achievement. The results seemed to validate the idea that planned professional development efforts aimed at improving performance must be linked among classrooms, teacher teams, the school and student outcomes in a conceptual and reciprocal fashion. A school's infrastructure must be designed in such a way as to guarantee learning support at all levels.

More recently, Allen and Penuel (2015) conducted a study focused on teachers' judgments of the coherence of professional development related to the Next Generation Science Standards (National Research Council, 2013) with larger system goals as well as their use of sensemaking to reconcile issues of perceived incoherence. Teachers' perceptions of coherence influenced decision making about the use of newly acquired learning and resources from professional development in their classrooms. [The concept of sensemaking is borrowed from organizational theory and describes how the unknown is structured (Waterman, 1990) within schools and other organizational settings. Sensemaking is used to resolve ambiguity and handle uncertainty in the environment and make sense of change.]

Results from the study indicated that the most common sources of ambiguity and uncertainty for teachers were conflicting goals, an absence of measures to gauge successful

implementation, and lack of resources to execute in the classroom adequately. Limited time coupled with inadequate curriculum materials made it difficult to implement fully the instructional strategies learned during the professional development. Having enough time available to adapt lessons and assessments to cohere with the vision of the new science standards proved especially challenging. Teachers had to navigate the conflicting goals of the professional development with their school and district level goals which included pacing guides, teacher evaluation protocols and local assessments. It was only when teachers were afforded opportunities to engage in sensemaking with each other that they were able to resolve perceived incoherence between the goals of their local contexts and the professional development. Sensemaking is a social pursuit and can serve as an opportunity for "active learning" that enables teachers to reconcile issues of coherence. Allen and Penuel (2015) suggest that professional development leaders should provide opportunities for active learning around issues of coherence just as they do for content so that sources of ambiguity and conflict can be resolved.

The attention that coherence is receiving as a critical component of professional development and the daily practice of teachers is exemplified by the publication of a special issues brief on creating coherence which targeted state policymakers and education leaders. The Center on Great Teachers & Leaders at the American Institute for Research outlined steps which can be taken to align goals of often disconnected reform initiatives being implemented concurrently (e.g., Common Core State Standards, teacher evaluation, and professional learning reforms) (Leo & Coggshall, 2013).

Core Elements and Evaluation of Teacher PD Programs

Contexts from school to school can vary dramatically, and what may work well in one may not always work well in another. Guskey (2009) suggests the identification of a set of core elements that can be adapted to specific contexts rather than a rigid, absolute set of best practices for professional development. Potential examples of such elements include time, strong leadership, collaboration in problem solving, and a school-based orientation to PD. He indicates that effective school leaders plan all PD efforts with learning and learners at the forefront, that they acknowledge the importance of core elements and adapt them for their unique situation. Definitive results of impact on student outcomes provide information on how best to move forward on future professional development endeavors. In order to obtain such data, professional development leaders must be willing to conduct honest evaluations of the effectiveness of their efforts, but all too often they are reluctant to put themselves under the microscope. Providing evidence that your attempts at improvement are not hitting the mark is not a palatable prospect and could lead to unfavorable attention by employers (Guskey, 2000, 2005, 2009).

Evaluation is a tool which can be used to ensure that each link in the causal chain leading to student achievement is firmly established. Program providers often have their own perceptions regarding the effectiveness of their program. These are typically formed through anecdotal evidence, but without a systematic collection of data, these perceptions cannot be confirmed. Program providers may remain unaware of weaknesses in their program design preventing improvements from being made in these areas. Evaluation can reveal areas for program improvement especially when the program is ongoing.

Gaytan and McEwen (2010) proposed a model (as seen in Figure 3) for evaluation of professional development. The authors recommended five levels which must be followed in order without skipping a level. Each level should have a rubric that includes indicators of quality. In addition, they suggest that planning must reverse the order of the five levels and work backwards from the desired student learning outcomes. The model may be applied to teacher professional development in any discipline by inserting applicable indicators of quality at each level. Below is an adapted and more generalized model of the one proposed by Gaytan and McEwen (2010) and leaves out the indicators:

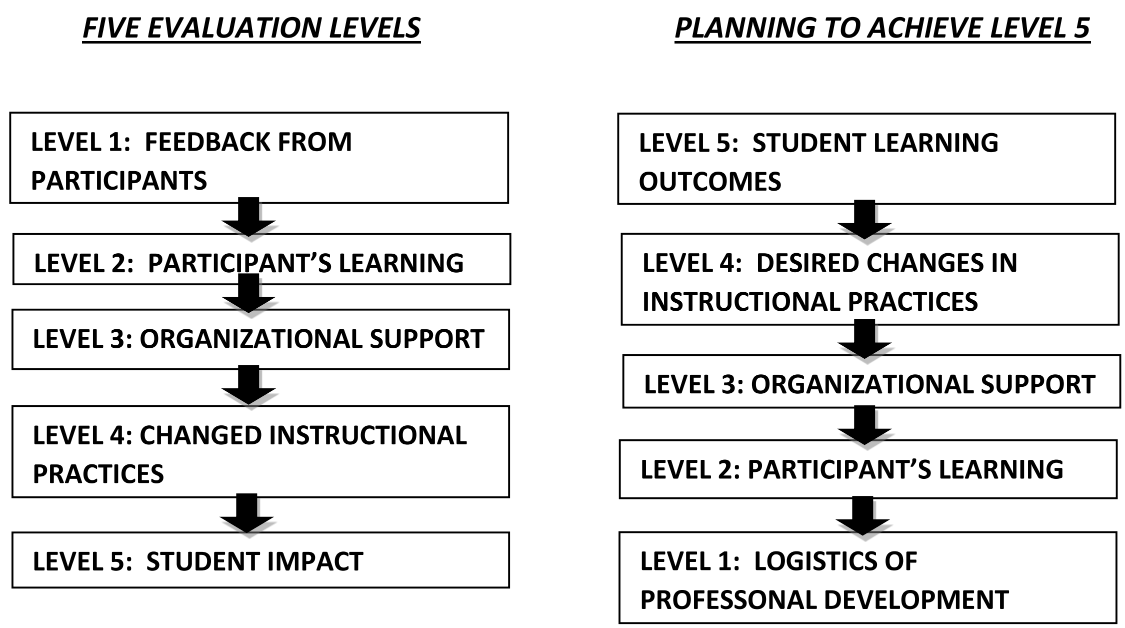

Figure 3. Evaluation Model for Professional Development for Teachers

Professional Development and Curriculum Use

There is some evidence that a change in curriculum which is aligned with reform efforts and the goals of a professional development agenda may result in increased teacher learning and impact on student achievement. A study by McCaffrey et al. (2001) involved a large urban school district that received grant money in association with NSF's Urban Systemic Initiatives

(USI) program. This district was one of 20 large urban districts with awards of up to $15 million dollars over five years supported by the USI program. High poverty areas were targeted, and the program aimed at providing systemic reform in the areas of science, mathematics, and technology from K-12. A common feature of the initiatives was a focus on professional development with a large portion of budgets often being allocated to teacher training. The mathematics reform efforts aligned with those outlined in documents produced by NCTM during this time, where problem solving, communication, reasoning, and mathematical connections were emphasized.

The district under study was chosen in part because of the variety of courses offered, including explicit curricula for both reform and traditional courses. The mathematics courses differed in the organization of the curriculum and the instructional practices recommended. The reform oriented courses were more aligned with the larger reform initiative underway in the district. The researchers examined the extent to which teacher use of reform-based instructional practices was related to improved student achievement after controlling for student background characteristics and prior achievement. It should be noted that the potential impact of student use of the curriculum materials was not taken into consideration. Some students were placed in the integrated math courses designed to be consistent with the reforms, while others were enrolled in more traditional algebra and geometry courses. All the math teachers involved in the study were receiving the same professional development supported by the USI program, but they found that professional development for teachers was more impactful on student achievement when coupled with changes in curriculum that were consistent with reform efforts (McCaffrey et al., 2001).

Use of Curriculum Materials as a form of PD

An explanation for such results may be the potential that curriculum materials themselves hold as a professional development tool when they are designed to be educative (Desimone, 2009; Loucks-Horsley, Hewson, Love, & Stiles, 1998; Remillard, 2005). The use of curriculum materials as a means of teacher development has received increased attention in the research literature in the past couple of decades, and recently attempts have been made to consolidate what has been discovered on the topic. Studies indicate teachers' interactions with curriculum materials can result in teacher change, and the connection of deep study of such materials with teacher learning in other countries gives further credence to this notion (Collopy, 2003).

Because curricular materials are deeply rooted in the day to day activities of teachers and are closely associated with classroom instruction, they possess the capacity not only to offer continued support in the areas of pedagogy and subject-matter content but to shape the beliefs and understandings of teachers (Blumenfeld et al., 1994; Guskey, 1988; Remillard, 2000). This approach to teacher learning is not uncommon in curriculum materials developed in Japan and China where teachers frequently reflect on the content in such materials to guide discussions and decisions in the classroom (Gill & Pike, 1995; Ma, 1999). In the US, teacher perception and use of curricular materials suggest that additional professional development may be needed to guide teachers in the effective use of these materials and maximize the opportunity for teachers to learn from the implementation process. The use of such materials as a means of providing professional development for teachers has appeal due to its scalability and its coherence with teacher practice (Collopy, 2003).

Collopy (2003) conducted a case study of two upper elementary teachers using curriculum materials designed to support teacher learning and provide a sequence of lessons for teaching students mathematics. The study sought to determine whether curriculum materials could be an effective professional development tool. The findings of this study support the conjecture that curriculum materials designed to foster teacher learning in the areas of pedagogy and mathematics can be effective. The results suggest that interactive experiences including reading the materials, enacting instruction and the use of the materials when collaborating with colleagues created opportunities for teacher learning to occur (Collopy, 2003).

Limitations of curriculum materials as a PD tool were illustrated in this study as well. While one of the two teachers in this study adopted a new approach to teaching mathematics, the other teacher did not experience a significant change in her mathematics instruction or in her beliefs and practices. The teacher who changed her instruction and thinking about mathematics teaching and learning during the year approached her interaction with the materials differently and had expectations that they would offer support in how and what to teach her students. The teacher whose practice was largely unaffected considered herself experienced and comfortable with her knowledge of mathematics. These cases point to the potential impact of interrelated beliefs on a teacher's construction of opportunities to learn which are tied to teacher knowledge and beliefs about pedagogy and mathematics and their identity as a teacher and a learner (Collopy, 2003).

Li, Ni, Li, and Tsoi (2012) conducted a study in central China where they examined the influence of curriculum reform on teachers' perceived instructional practices. There were 584

elementary math teachers surveyed, 390 of the teachers had implemented the reform-based curriculum while 194 teachers used the conventional curriculum. The researchers found that those teachers who used the reform-based curriculum were more likely than teachers using the conventional curriculum to report practices advocated by the reform such as group discussions, providing students with multiple strategies, and utilizing a variety of assessment types. Furthermore, these findings were confirmed by observations that the more time teachers participated in the reform, the greater the occurrence of reported use of instructional practices encouraged by the reform. Other factors contributed to the effect of the reform-based curriculum such as the number of years of teaching experience. There was a noticeably stronger effect for those teachers having less than eleven years of experience, who were more open to the instructional approaches presented in the reform-based curriculum. Although the reported reform-based instructional practices were positively correlated with teachers' perceptions around support, collaboration, and professional development, teachers from both groups reported about the same amount of opportunities in PD and they both reported high levels of support in their schools and opportunities to collaborate with colleagues.

Impact of curriculum materials on pre-service teachers. Studies involving the use of curriculum materials in the development of pre-service teachers has also provided evidence of the power of these materials to impact the user's previously held knowledge and beliefs. Frykholm (2005) examined the use of reform-based middle school mathematics curricula as a tool for professional development, specifically with pre-service teachers. The focus of this four-year study explored the degree to which repeated encounters with curriculum materials impacted prospective teachers': knowledge of mathematics, competency and

confidence; thinking about student learning; and formation of teaching philosophies and pedagogical practices. A core element of the study was the engagement of prospective teachers with the content and mathematical activities of modules that extended across four strands: number, geometry, algebra, and probability and statistics. The results of this study indicate that interactions with these materials by prospective teachers stimulated change in both their content knowledge and their beliefs about teaching and learning.

Spielman and Lloyd (2005) revealed the use of innovative curriculum materials in college classrooms guided by reform visions for instruction can significantly impact the beliefs prospective mathematics teachers hold about teaching and learning when compared to more typical college classroom settings that use traditional texts and are largely instructor led. The authors suggest that assessing the outcomes of such novel settings on teacher practice can inform the design of teacher professional development. The authors also highlight that when "mathematical subject matter is taught through curricular emphases that support reform objectives" (p. 40) key features of effective professional development are addressed.

A Framework for Studying Curriculum Use

Remillard's (2005) survey of 25 years of research on the use of mathematics curriculum by teachers revealed significant variation in findings and in theoretical foundation. Curriculum use took on multiple meanings across the 70 studies analyzed for the study. The four primary ways curriculum use has been conceptualized and examined in the research arena include curriculum use as following the text, drawing on the text, interpreting the text and participating with the text. The final two categories have some overlap and are emphasized in the framework put forth by Remillard for characterizing and studying the interactions teachers

have with curriculum materials. The two assumptions which are fundamental to Remillard's model are that teaching is multifaceted in nature and involves curriculum design.

Assumption 1. Teaching has a multidimensional nature, and it consists of more than just what takes place with students in the classroom. There are two studies of curriculum use which produced models that characterize the various dimensions of teaching as it relates to curriculum (Remillard, 1999; Sherin & Drake, 2004). Remillard (1999) identified three arenas of curriculum development activity: the *design arena*, the *construction arena* and the *mapping arena.* Teachers make decisions in each of these arenas. For example, teachers select and design tasks in the *design area*. The *construction arena* is the implementation of the planned tasks in the classroom and involves teachers responding as students engage in the tasks. Finally, the *mapping arena* is related to the decisions teachers make about the organization and content of the mathematics curriculum over the course of the school year.

A second model was proposed by Sherin and Drake (2004) through their analysis of 10 elementary teachers' implementation of a non-commercially published math curriculum. This model includes three processes teachers participate in when using curriculum materials: reading, evaluating and adapting. The researchers examined when teachers read the materials and for what purpose and identified three common techniques: 1) reading for big ideas before instruction, 2) reading for lesson details before instruction, and 3) reading for big ideas before instruction and for details during instruction. The last method was linked to teachers who were able to meet the broader objectives of the lessons as well as distinct components. *Evaluating* denotes the assessment of various elements of the materials from both a content and pedagogical perspective with either a focus on teacher or student considerations. *Adapting*

refers to the changes made by teachers between the written and enacted curriculum. This process is thought to occur somewhat simultaneously with *evaluating* as teachers make decisions about the structure of the lesson, which activities will be included, materials needed for the lesson, etc. Sherin and Drake suggest that a teacher's curriculum strategy, at least during the first year of implementation, is somewhat stable.

Assumption 2. As teachers interact with curriculum materials, plan and enact learning experiences for their students, they are engaging in the work of curriculum design. Teachers do not merely transmit the written curriculum, but they make choices and manipulate the materials (Clandinin & Connelly, 1992; Remillard 2005) for their students in the specific context of their classrooms (Ben-Peretz, 1990). As teachers enact planned tasks, the unscripted responses of students make it necessary for teachers to make spontaneous decisions about amending tasks (Remillard, 2005; Stein, Grover, & Henningsen, 1996). *Design* demonstrates the artful nature of the teaching craft and its in-process qualities. "The notion of design connects powerfully to the sort of creative intelligence the best practitioners need in order to be able, continually, to redesign their activities in the very act of practice" (New London Group, 1996, p.5).

Conceptions of curriculum materials. Another important premise of Remillard's framework relates to the nature of curriculum materials. Otte (1986) asserts the objective and subjective nature of texts. Curriculum materials can be differentiated by the objectively given elements which distinguish them from one another–the physical aspects of the curriculum which define how mathematics and learning activities are presented and structured (Remillard, 2002; Remillard, 2005). Such structures may take on the form of daily lessons which seek to

direct the actions of teachers through the suggestion of particular activities with students. The authors' beliefs about how mathematics should be taught and learned are implicitly communicated through these structures. Some curriculum materials are more explicit in addressing teachers and are designed to be educative, finding ways to speak directly to the teacher (Remillard, 2000; Remillard, 2005).

"Subjective schemes encompass tradition and culture and mediate the reader's interpretation of the objective structure" (Remillard, 2005, p. 229). From a conceptual perspective, knowledge and how that knowledge should be taught and learned must be translated into written word by the authors of curriculum materials (Remillard, 2005). The text and visual representations provided to teachers are then interpreted and implemented in the classroom in considerably different ways (Brown, 2002; Remillard, 2002). The context in which an educator teaches along with their previously held knowledge and beliefs impact how materials are interpreted, modified and enacted with their students. From a practical perspective, no set of curriculum materials can be developed to address the needs that arise in every classroom in every school (Remillard, 2005), but direction can be provided to teachers on how to make the necessary adjustments for their particular students in a given situation.

Framework of the teacher–curriculum relationship. Remillard's (2005) framework embraces curriculum use as a participatory relationship between the teacher and the curriculum and demonstrates that the interaction is shaped both by what the teacher and the curriculum bring to the relationship. The four core constructs of the framework include 1) the teacher, 2) the curriculum, 3) the participatory relationship between them and 4) the planned and enacted curricula which result.

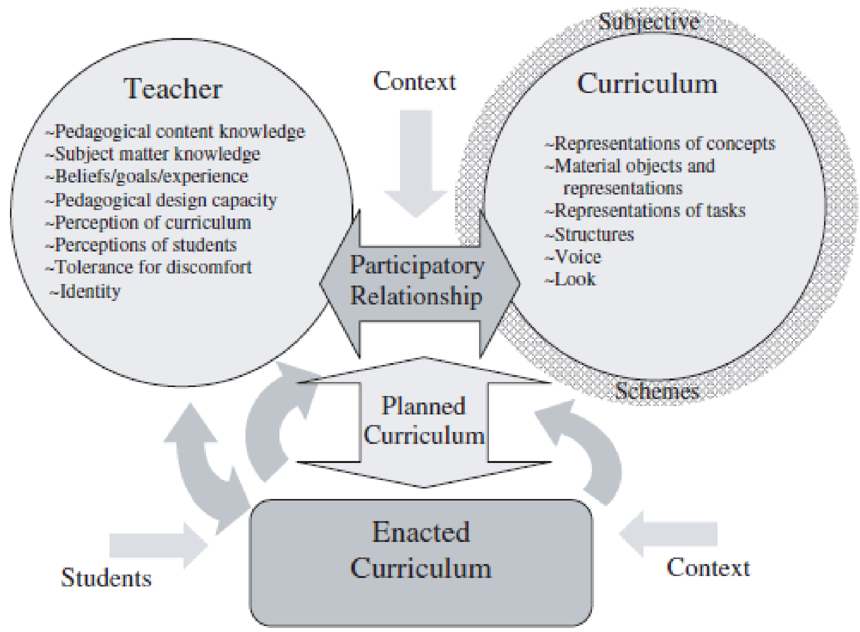

Figure 4. Framework of components of teacher–curriculum relationship (Remillard, 2005)

Teachers are unique as are the contexts in which they teach. No two teachers share the same set of beliefs, goals and experiences. The various characteristics, resources and perceptions teachers bring to the participatory relationship impact how they interact with the curriculum. The framework suggests influence not only by the knowledge teachers hold (i.e., pedagogical content knowledge and subject matter knowledge) but also from their capacity for pedagogical design. Perceptions about the curriculum and their students also serve as influential factors as do professional identity and tolerance for discomfort (Remillard, 2005).

The circle on the right in Figure 4 above is representative of the specific curriculum resource being used. Since less is known about how the features of a particular curriculum affect the teacher-curriculum interaction, the elements listed under curriculum in the model are more tentative than those listed for the teacher and require further examination. The outer circle signifies how the curriculum and its features are perceived by the teacher and by

the larger educational community–the curriculum as a subjective scheme. These perceptions provide context for teacher encounters with the structural and more objectively given features of the curriculum such as the representations of objects, concepts and tasks. Voice, look and structure are not particularly related to the content and are more subtle in nature but are believed to be worthy of continued exploration to validate how and to what extent such features make a difference in the teacher-curriculum relationship (Remillard, 2005).

The interactions which take place between the teacher and the curriculum result in the planned curriculum, what the teacher anticipates happening in the classroom. The enacted curriculum is what actually takes place in the classroom when the planned curriculum is put into action with particular students. The enacted curriculum is part of the curriculum design process where the teacher continues to shape the lesson activities based on emerging demands in a specific context. The teacher and students together contribute to the construction of the enacted curriculum. The arrows on each end of planned curriculum element in the framework show the potential for impact not only on the enacted curriculum but also on the participatory relationship as it molds how teachers interact with the curriculum resource (Remillard, 2005).

The path in the framework actually illustrates one that is "cyclical and dynamic" (Remillard, 2005, p.239) which is denoted by the use of arrows from the enacted curriculum to other major components. This also signifies that enacting curriculum can result in teacher learning and change.

Maximizing the Potential of Curriculum Use

The current literature suggests that offering professional development to support teachers when implementing a standards-based curriculum is fairly typical but may not be

enough. There is evidence that teachers working together through the mathematics of lessons, analyzing from a learner's perspective and thinking about the progression of the mathematics can be a powerful experience. Understanding how schools and districts ensure that its teachers take part in meaningful learning experiences such as these is key. Making sure teachers have time to meet on a regular basis with other math teachers at the same grade level is one way to support this type of engagement with curriculum materials. Setting agendas, having clear goals, bringing copies of curriculum materials and student work are best practices for these types of collaborative meetings. Outlining norms and expectations for participants are additional steps that can be taken to assist in generating productive discussions and analysis. Districts could also benefit from the development of teacher leaders who can guide their colleagues through the mathematics in the curriculum materials and the examination of their beliefs and assumptions about teaching and learning that frame their practice (Davenport, 2009).

Teachers need continued opportunities to work through and analyze lessons in deliberate ways with other educators if they are to experience the full potential curriculum materials have to offer and to maximize their support of student learning. Furthermore, teachers' continued engagement with curriculum materials can result in increased trust which can further shape the way teachers use the materials (Drake & Sherin, 2009).

In Conclusion

The research is clear that teacher professional development has consistently lacked rigorous evidence of significant impact on teacher and student learning, but the reason for such results remains in question. There is continued confidence that developing teachers

professionally is the means for moving our nation towards increased student performance (Garet et al., 2010, Hill et al., 2013) not only in mathematics but in all core subject areas.

Although the features associated with effective PD have been widely accepted for some time, their presence alone does not appear to be enough to guarantee the type of teacher and student outcomes such experiences are intended to produce. Of these five features, coherence appears to be the most influential characteristic of professional development on teacher practice. Having an integrated PD program which aligns with teacher practice holds promise for realizing substantive change in teachers and their classrooms.

Use of educative curriculum materials as a form of professional development has been shown to have the potential to bring about change in the attitudes, beliefs, knowledge, and practice of teachers. It would be challenging to think of another PD experience that is more aligned and coherent with the work teachers do in the classroom. Implementation of curriculum materials that are consistent with the objectives of reform efforts and provide opportunities for teacher learning can serve as an anchor point around which a coherent professional development program can be built—a program using a holistic approach where formal, informal, and independent professional development are integrated toward a common goal.

Recent reform efforts in the area of mathematics brought about by the adoption and implementation of the CCSS have created a prime opportunity to study teacher curriculum use and extend what we know about how teachers use curriculum and the potential these materials hold for bringing about change. The literature points to the need for answering the many questions surrounding how to enhance the transfer of knowledge and skills acquired by

teachers through professional development to their instructional practice (Leberman, McDonald & Doyle, 2006; McGee et al., 2013) and how such findings can inform professional development leaders about how to facilitate teacher change and improvement in student outcomes (McDonald, 2012). Kazemi and Hubbard (2008) state that it should be considered a priority to establish clearly the nexus between the acquisition of new knowledge and skills and their implementation in the classroom.

The literature is also clear about the need to acquire more knowledge about how teachers learn from their participation with curriculum materials and how district and school leaders can best support teacher learning. "The more we know about this process of learning through and from …curriculum materials, the better prepared we can be to address this important need" (Davenport, 2009, Chapter 24, p.7621). Understanding how teachers use educative curriculum materials, the types of changes that take place as a result of their use, and how the decision making process unfolds would be significant additions to the existing body of literature and provide new directions for research. This study attempts to make contributions to mapping out connections in the teacher change process as result of curriculum use and add to the somewhat crude causal model for teacher development.

CHAPTER 3
METHODOLOGY

This chapter outlines the methodology employed in the present study and provides an explanation of procedures including sampling, data collection procedures, instrumentation, and data analysis. A mixed method sequential explanatory design was implemented in this study with two distinct phases. First, a survey was administered to teacher participants including Likert-scale items and opened-ended questions. After analysis of the data from phase one was complete, interviews were conducted with teachers and district leaders in an effort to explain, clarify, and enhance the data from the survey administration.

The focus of the most recent K-12 reform effort in mathematics education at the national level has centered on the implementation of the Common Core State Standards for Mathematics. Over time, existing curricular materials have been revamped and in some cases new materials have been developed to align with the new standards. The CCSSM calls for shifts in the way teachers conduct their practice, creating favorable conditions in the field to study how teachers use curricular materials as a professional development tool and what impact this use has on teachers and their practice. *Eureka Math* curriculum materials were selected for this study not only because of their strong alignment to the new standards based on an impartial third-party review, but also due to its unique characteristics and educative style.

Sampling

A criterion sampling technique (Collins, Onwuegbuzie, & Jiao, 2007) was employed to select three school districts from the same southern state. Selection was based on a strong commitment to implementing *Eureka Math*, willingness to participate, size of the district, and

proximity to the researcher. A preliminary investigation around the use of curriculum materials in the state revealed districts using *Eureka Math*. In an attempt to maximize sample size for the quantitative portion of the study, smaller districts were only considered for piloting the survey. Two districts were contacted to participate in the pilot, with one agreeing to take part. The four districts with the most evidence of implementation fidelity were contacted regarding participation in the full study. Of the four districts contacted, three were willing to participate.

A contrast school district in the same state was sought in order to provide comparison data for phase one of the study. Of the three school districts contacted who had adopted a curriculum other than *Eureka Math*, one was willing to have their teachers participate. The contrast district began implementing their new curriculum during the 2014-2015 school year.

School District 1 has 25 schools and enrollment numbers near 14,000, with 10% classified as special education (SPED) and 73% economically disadvantaged. School District 2 is the largest district by far with a total of 42 schools and enrollment numbers close to 30,000 students. The SPED population is 7%, and 62% of students are classified as economically disadvantaged. School District 3 serves almost 10,000 students across 19 schools. It also has a SPED population of 10%, and 62% are labeled as economically disadvantaged. This data was taken from 2014-2015 district report cards on the state department website. The contrast school district, implementing a different mathematics curriculum, had 23 teachers participate in the survey which was sent out to 9 elementary schools. This district has a total of 18 schools and an enrollment of about 8500 students. Their SPED population is 10%, and 74% of their students are considered economically disadvantaged. This district is slightly smaller than the

smallest district implementing *Eureka Math*, but it does not differ much from the other districts in terms of the number of special education and economically disadvantaged students.

Third through fifth grade math teachers were targeted for participation in this study due to similarities across these grades in the major concepts covered as well as the problem solving strategies and models utilized. In phase one of the study, district level leaders granted permission to send surveys to third through fifth grade teachers in 50 elementary schools implementing Eureka Math and 7 elementary schools in the contrast district. The table below provides demographic information related to participants' teaching experience.

Table 3.1

Descriptive Statistics for Teachers Participating in the Survey

	District 1 Mean (SD)	District 2 Mean (SD)	District 3 Mean (SD)	Combined Mean (SD)	Contrast District Mean (SD)
Years teaching	14.73 (10.19)	12.89 (8.18)	15.05 (8.04)	14.14 (8.92)	13.48 (7.21)
Years teaching math	13.62 (10.20)	11.99 (7.84)	13.48 (7.89)	12.98 (8.76)	12.00 (7.38)
Years teaching new curriculum	2.83 (.80)	2.90 (.70)	3.05 (.70)	2.91 (.74)	1.64 (.79)

Eureka Math implementing districts agreed to have up to three teachers interviewed from a single school site in their district and one district leader with intimate knowledge of the curriculum's implementation. This selection of teacher and district level participants for phase one and two of the study employed multilevel sampling which involves the use of two or more sets of samples extracted from different levels of the investigation (Collins et al., 2007).

Each district leader designated a school in their district where selections would be made for teacher interviews and obtained the principal's permission to conduct interviews with their teachers. Two of the designated schools were K–5 elementary schools and one was K–4. One teacher at each grade level in each school was chosen at random for a total of eight teacher interviews. The schools selected had student populations around 500 to 600 and classifications of 6–12% SPED and 54–68% economically disadvantaged students. None of the three schools selected were ranked at the top of their district in terms of school scores, but they were not the lowest performing schools either. District contacts assisted in selecting a district leader with significant insight into the implementation of the curriculum for interviews.

An application for exemption was submitted to the Institutional Review Board (IRB) at Louisiana State University to conduct the study. After approval was granted, data collection began.

Data Collection Procedures

Table 3.2 provides a summary of the data collection procedures taking place during phase one and two of the study as well as preliminary work which took place during the pilot. The data collection strategies applied during both phases of the study are described in greater detail in the sections which follow.

Phase One

The survey was sent out electronically to all third through fifth grade teachers in the districts implementing *Eureka Math* as well as the contrast district. The introductory email requesting teacher participation and the language included at the top of the survey addressed

Table 3.2

Sequence of Data Collection Procedures

Phase	Activity	Description
Pilot	Administration of survey	Dissemination of electronic survey to third, fourth and fifth math grade teachers in the pilot district
	Analysis of survey results	Survey results analyzed and used to make minor modifications to the initial survey created
One	Administration of survey	Dissemination of electronic survey to third, fourth and fifth math grade teachers in participating districts
	Analysis of survey results	Survey results analyzed and used to hone and expand the initial set of interview questions crafted
Two	Conduct interviews	Interviews conducted with 8 teachers at grades 3, 4 and 5 from three districts Interviews conducted with one leader from each district

issues of confidentiality. Participants were given approximately two weeks to complete the survey with reminders sent by email one to three days prior to the survey closing. The data obtained from the survey were analyzed prior to the second phase of data collection consisting of interviews with teachers and leaders from each district. Results from the survey were used to hone and expand the initial set of interview questions crafted in order to probe more effectively during the interview process and further clarify and explain survey results.

Survey instrument. An online survey software tool was used to create the instrument for phase one of this study, and a complete copy of the survey can be found in Appendix B. The survey

opened with a few questions designed to collect information related to participants' teaching experience (i.e., the number of years each participant had been in the classroom, had taught math, and had been teaching Eureka Math) as well as the grade level(s) at which they were currently teaching. The next section of the survey included four sets of Likert scale items, each designed to measure the following: *teacher practice*, *coherence of the PD program, opportunities to collaborate*, *and curriculum use*. The survey closed with three open-ended questions related to changes teachers experienced as a result of using *Eureka Math* curriculum materials. Each of the four scales are described in further detail below.

Teacher practice. The teacher practice scale was designed to collect information about participants' current teacher practice (after using *Eureka Math*) as well as their practice prior to implementing *Eureka Math.* This scale was developed using a retrospective pre-post design. Instead of having participants answer questions before engaging in an activity and then answer the same questions again after, the retrospective pre-post design collects this information at the same time. This design takes less time, is less intrusive than a traditional pre-post design and eliminates pretest sensitivity and response shift bias which can accompany self-reported changes. Response shift bias occurs as a result of participants using a different frame of understanding when answering a question between the pre and post interval. Exposure to an activity or program can alter a participant's understanding or interpretation of the survey questions and create a different frame of reference and mask true effects. Results from the retrospective pre-post design have shown to be more aligned with interview data collected from participants than those from the more traditional pre-post design (Howard, Millham, Slaten & O'Donnell, 1981). Collecting data from participants in a single sitting also reduces the

chance of missing data. There are some limitations associated with the retrospective pre-post design. The ability for participants to recall past events and label them accurately after some time has passed varies and may impact responses provided by participants (Program Development and Evaluation, 2005).

The items included on this scale reflect teaching practices associated with the *Eureka Math* curriculum, some which might be considered atypical of more traditional curriculum materials. The practices are thought to be reflective of a teacher who has adapted their teaching to align with those illustrated in *Eureka Math,* and many are reflective of the shifts called for by the CCSSM. First, teachers were asked to think about their current teaching practice and indicate the extent to which they agreed with each scale item. Next, teachers were asked to think about their teaching practice prior to using *Eureka Math* and provide responses for the same set of scale items. A 5-point scale was used with values ranging from 0 to 4, where 0 = do not agree at all, 1 = agree to a minimal extent, 2 = agree to a moderate extent, 3 = agree to a good extent, and 4 = agree to a great extent. Teacher responses to the items were averaged to create composite measures for each participant on each dimension of *teacher practice*.

Coherence of the PD program. Items measuring *coherence of the PD program* (see p. 3 for definition) were created for this study, modeled after an instrument used in a study by Garet et al. in 2001. Teachers were asked to indicate the extent to which the professional development activities organized by their school or district were consistent across the PD program and were aligned with the work they do in the classroom, their knowledge and beliefs, state standards, curriculum frameworks, and state assessments. Teachers were asked to report

responses on a 5-point scale with values ranging from 0 to 4, where 0 = not at all, 1 = to a minimal extent, 2 = to a moderate extent, 3 = to a good extent, and 4 = to a great extent. Teacher responses to the items were averaged to create a composite measure of PD program coherence.

Opportunities for collaboration. The scale measuring opportunities for collaboration was specifically created for this study but was modeled after items used in the *Illinois 5 2012-2013 Essentials Survey*. The items developed for this scale were meant to capture the ways teachers might collaborate with one another around curriculum implementation. Activities described in these items include teachers working together in ways that provide opportunities for informal professional development and sensemaking around issues of perceived incoherence. Teachers were asked the extent to which they had opportunities to engage in specific types of activities and were asked to report responses on a 5-point scale with values ranging from 0 to 4, where 0 = not at all, 1 = to a minimal extent, 2 = to a moderate extent, 3 = to a good extent, and 4 = to a great extent. Teacher responses to the items were averaged to create a composite measure for *opportunities to collaborate*.

Curriculum use. The final scale on the survey was developed to measure curriculum use, the way teachers interact with *Eureka Math* curriculum materials. The items reflect three types of activities teachers might engage in with curriculum materials: studying for big ideas, studying for details, and studying to customize. The selection of activities was influenced by Sherin and Drake's 2004 study of a small sample of elementary teachers' implementation of a non-commercially published math curriculum. Their study suggests that teachers enact a

particular curriculum strategy which is somewhat stable across the first year of implementation. As trust builds in the curriculum, teacher use may be adjusted.

The *curriculum use* scale items describe the types of activities *Eureka Math* curriculum developers intended its users to engage in during implementation. Such use would be expected to support teachers in making connections across modules as well as topics and in developing understanding of the mathematical progression through the grade. In addition to providing teachers with the broader view of the mathematics taught across the year, the activities reflected in the *curriculum use* scale also provide support in more detailed aspects of instruction such as executing specific lesson components, formulating questions for use during lessons, and teaching specific problem solving strategies which might be unfamiliar. Finally, the scale presents activities typically engaged in by more advanced users of the curriculum. These involve analysis of teaching sequences within the materials and the work their students produce in an effort to customize lessons to meet the needs in their own classroom.

Teachers were asked the extent they engaged in specific types of activities with *Eureka Math* curriculum materials and were asked to report responses on a 5-point scale with values ranging from 0 to 4, where 0 = not at all, 1 = to a minimal extent, 2 = to a moderate extent, 3 = to a good extent, and 4 = to a great extent. Teacher responses to the items were averaged to create a composite measure of *curriculum use*.

Validity and reliability of scales. To determine the reliability and validity of the four scales described above, the survey was administered to a pilot group of 14 upper elementary school teachers before the study began. Analyses were then conducted on each scale and

adjustments were made based on the results. Cronbach's Alpha values for each of the scales are displayed in Table 3.3.

Table 3.3

Results of Reliability from Pilot Survey Administration

	No. of Questions	Cronbach's Alpha
Curriculum Use	9	.77
Opportunities to Collaborate	6	.89
Coherence of the PD Program	6	.97
Teacher Practice (Now)	12	.84
Teacher Practice (Prior to using *Eureka Math*)	12	.90

Open-ended questions. The open-ended questions included at the end of the survey were meant to capture information on the specific types of changes teachers experienced as a result of using *Eureka Math* curriculum materials. The following questions were included:

1. Since using Eureka Math, what changes have occurred in your beliefs about teaching and/or learning mathematics?
2. What new knowledge or skills have you gained from using *Eureka Math* curriculum materials?
3. Describe the changes in your practice which occurred as a result of using *Eureka Math*.

These questions allowed teachers to express in their own words the changes (if any) that had taken place in their beliefs, knowledge, and practices since using implementing the new curriculum. The third question was designed to complement the quantitative data collected from the teacher practice scale.

Phase Two

After analysis was complete on the data from phase one, interviews were conducted with teachers and district leaders in an effort to explain, clarify, and enhance the data from the survey administration. Teacher interviews were held over a two-week period at each of the school sites selected by district leaders. Interviews with district leaders also took place during this time frame. Each interview lasted approximately 15-45 minutes, and each was recorded with the permission of the participants and later transcribed. The questions asked of teacher participants were designed to gain a better understanding of the following: use of curriculum materials over time, how the change process unfolded, and how the formal, informal and independent modes of professional development supported their implementation efforts and the changes teachers made to their practices. Using a standardized open-ended interview approach, teachers were asked the following questions:

1. How many years have you been in the classroom teaching?
2. How many years have you been using *Eureka Math*?
3. Since you have been using *Eureka Math*, what changes have occurred in your beliefs about teaching and/or learning mathematics?
4. What new knowledge or skills have you gained from using *Eureka Math* curriculum materials?
5. Describe the types of changes in your practice which occurred as a result of using *Eureka Math*. Please provide examples where appropriate.
6. Tell me how decisions related to changing your practice came about. How did the change process unfold?

7. Provide examples when the curriculum called for doing something differently in terms of your classroom practice and you chose not to make a change. What contributed to those decisions?
8. Describe how you use the curriculum materials both when preparing to teach lessons and during class time. If your use of the materials has changed over time, please describe those changes.
9. Thinking about the types of professional development teachers can engage in (i.e., formal PD, informal PD such as PLCs, and independent learning) tell me:
    - how well you feel these experiences were integrated into a cohesive program with common goals.
    - how well aligned these experiences have been with the work you do in the classroom.
    - about your opportunities to collaborate with other colleagues about *Eureka Math*.

Interviews with districts leaders provided context for the data obtained both quantitatively and qualitatively from the teachers. Their responses contributed further insight into the implementation of *Eureka Math* in each district and provided information on the support teachers received while using the curriculum. Using a standardized open-ended interview approach, leaders were asked the following questions:

1. Tell me about the district's implementation plan for *Eureka Math*.
2. Were there any instructions provided on how teachers should approach the use of curriculum materials?

3. Describe the formal PD experiences that have been provided to teachers in your district on *Eureka Math*.
4. What has the district's capacity been to allow time for teachers to collaborate on *Eureka Math*? Are there particular structures in place to support this type of teacher interaction?
5. Were there any other ways that the district or schools supported teachers in their implementation of *Eureka Math* that we haven't discussed already?

Data Analysis

Data analysis is described below and organized according to research questions. The following table displays a summary of the data collection strategies used to answer each of the three research questions.

Table 3.4

Research Questions and Data Collection Strategies

Research Question	Data Collection Strategy
1. What changes in beliefs, knowledge, and classroom practice do teachers attribute to their use of *Eureka Math* curriculum materials, and is there a statistically significant difference between teacher practices now and practices prior to implementing the curriculum?	Likert scale items from the survey, open-ended questions from the survey, interviews
2. How does teacher use of curriculum materials develop across multiple years of implementation?	Likert scale items from the survey, interviews
3. What factors (i.e., curriculum use, opportunities to collaborate, coherence in the PD program, and number of years teaching) predict change in teacher practice?	Likert scale items from the survey, interviews

Teacher Change

The first research question was answered using both quantitative and qualitative data. Descriptive statistics were generated for survey items from the *teacher practice* scales. A

Paired Samples t-Test was conducted to determine if there was a statistically significant difference between teacher responses about their practice prior to using *Eureka Math* and responses about their practice after using the curriculum. The open-ended questions from the survey administered were examined for patterns and trends. Coding categories were developed for the various themes noted in the data. Each participant response was labeled with one or more of the coding categories. Sub-coding categories were developed as needed. The interview data were used to verify the findings from the survey data and to explain the decision making involved in the change process.

Curriculum Use

To answer the second research question, descriptive statistics were generated for survey items from the *curriculum use* scale to explain how teachers currently interact with *Eureka Math* curriculum materials. Responses to interview question 8 (*Describe how you use the curriculum materials both when preparing to teach lessons and during class time. If your use of the materials has changed over time, please describe those changes.*) were also analyzed to provide additional insight into how teachers have used the curriculum materials over time both when preparing to teach lessons and during class time. The transcriptions from this teacher interview question were examined for common themes and coded.

Factors Predicting Teacher Change

The final research question was answered using stepwise multiple regression analysis to provide the correlations between variables, to determine the significance of the relationships between variables, and to build a model which explains variation in change in teacher practice. Multiple regression analysis was selected rather than separate simple regression analyses to

identify the linear combination of the independent variables that is maximally correlated with the dependent variable. The stepwise method was used in order to remove independent variables not making a significant contribution to the model.

Assumptions of normality, linearity and homoscedasticity were checked as well as whether the independent variables were measured without error. Histograms were generated to check for normality as were normal probability plots. Scatterplots were used to check for linearity and a plot of the standardized residuals were generated to check for homoscedasticity. Correlations were examined as a check for possible collinearity between independent variables as well.

CHAPTER 4
PRESENTATION OF RESULTS

The purpose of this mixed method sequential explanatory study was to understand how the implementation of *Eureka Math* curriculum materials impacted upper elementary teachers from three southern school districts. In addition, this study aimed to identify whether factors including curriculum use, opportunities to collaborate, coherence of the PD program and teaching experience predict change in teacher practice. This study was carried out in two phases using both quantitative and qualitative methods. This chapter presents the results of the analysis of the data collected from the three sample school districts and one contrast district. The results are presented in the following order: 1) survey response details 2) descriptive statistics from the survey 3) results of analyses and findings for each of the three research questions and 4) information on reliability and validity.

Approximately 500 3^{rd}–5^{th} grade teachers across the three school districts implementing *Eureka Math* received the survey email. Usable surveys were returned by 123 teachers—46 teachers from School District 1, 45 teachers from School District 2, and 32 teachers from School District 3—which translates to a response rate of about 25%. The survey administration email was sent to the seven elementary schools with grades 3–5 in the contrast school district, and 23 usable surveys were returned. The surveys were administered in the last month of the school year right after state standardized testing concluded.

Interviews with district leaders revealed similarities among the approaches to implementation across the districts implementing *Eureka Math*. Districts provided formal professional development to their teachers on the modules in the curriculum during year one and in successive years. Resources were sought out by districts and shared with teachers.

Some districts had resources available to create supplemental materials such as parent newsletters, digital presentation tools, and assessments deemed to be more like what students would see on state standardized assessments. Not only were district leaders from each of the three districts in frequent contact with one another during implementation, but they also shared resources with one another whether found or created. The collaboration and sharing of information across districts is likely a possible contributing factor to the similarities in shifts among teachers in the three districts implementing *Eureka Math*.

For the districts implementing *Eureka Math*, the sample mean for number of years in the classroom was 14.14, and the sample mean for the number of years teaching mathematics was 12.98. Although the sample mean for number of years teaching *Eureka Math* is 2.91, this number is believed to be inflated based on some of the reported values being larger than the actual number of years *Eureka Math* has been in existence. The first year that a school could have fully implemented the program at the elementary level is the 13–14 school year which means that three years should be the maximum number represented. Furthermore, in conducting the interviews, it was not uncommon for teachers who had been implementing the longest to recall how many years they had actually been using the program inaccurately. As seen in Table 4.1, the information related to teaching experience was similar across all three districts implementing *Eureka Math* as well as the contrast district.

The table provides additional descriptive statistics from the survey for each district as well as all three districts combined and the contrast district. According to survey results, the mean value for *teacher practice* prior to using *Eureka Math* was 2.63 while the

mean value for *teacher practice* after using the curriculum was 3.35. This resulted in a mean for *change in teacher practice* of .72. The sample mean value for *curriculum use* at 3.18 reveals

Table 4.1

Descriptive Statistics for Districts Implementing Eureka Math and the Contrast School District

	District 1 Mean (SD)	District 2 Mean (SD)	District 3 Mean (SD)	Combined Mean (SD)	Contrast District Mean (SD)
Years teaching	14.73 (10.19)	12.89 (8.18)	15.05 (8.04)	14.14 (8.92)	13.48 (7.21)
Years teaching math	13.62 (10.20)	11.99 (7.84)	13.48 (7.89)	12.98 (8.76)	12.00 (7.38)
Years teaching new curriculum	2.83 (.80)	2.90 (.70)	3.05 (.70)	2.91 (.74)	1.64 (.79)
Teacher practice after using new curriculum	3.37 (.68)	3.29 (.80)	3.43 (.58)	3.35 (.70)	3.40 (.49)
Teacher practice prior to using new curriculum	2.83 (.78)	2.45 (.91)	2.62 (.93)	2.63 (.88)	3.28 (.53)
Change in teacher practice	.54 (.99)	.84 (1.25)	.81 (.82)	.72 (1.06)	.13 (.41)
Curriculum use	3.18 (.83)	3.12 (.86)	3.23 (.64)	3.18 (.79)	---
Coherence of the PD program	3.03 (.90)	3.00 (1.03)	3.41 (.77)	3.12 (.92)	3.11 (.58)
Opportunities to collaborate	2.50 (1.08)	2.28 (1.26)	2.51 (1.07)	2.43 (1.13)	3.17 (.65)

that, generally speaking, teachers have taken part in the types of activities with the curriculum materials intended by *Eureka Math* developers. The survey revealed that teachers on average believe that the PD program in their school/district is coherent *to a good extent*–3.12, while numbers for their opportunities to collaborate were somewhat lower with a sample mean of

2.43. Closer examination of the survey results for each measure (i.e., *curriculum use*, *teacher practice*, *coherence of the PD program*, and *opportunities to collaborate*) is done within the context of the three research questions addressed in the sections that follow.

Teacher Changes as a Result of Using *Eureka Math*

The Likert scale items for *teacher practice* on the survey were designed to provide data related to changes in teacher practices as a result of using *Eureka Math* while the open-ended responses of the survey provide data on change in teacher practice as well as changes to teachers' beliefs and knowledge. The quantitative and qualitative data collected from these sources were examined, along with data collected from teacher interviews, to answer the first research question.

Teacher Changes: Quantitative Survey Results

According to survey results, the mean value for *teacher practice* prior to using *Eureka Math* was 2.63 while the mean value for *teacher practice* after using the curriculum was 3.35. Mean values for *teacher practice* after using *Eureka Math* were higher for every item on the scale than the corresponding mean values for *teacher practice* prior to use. These differences indicate teachers viewed their instruction as more aligned with the activities specified in the items of the *teacher practice* scale, and therefore those associated with *Eureka Math*. Table 4.2 provides more detailed information about the results of the t*eacher practice* survey items. By far, the item indicating the greatest degree of change with a *change in teacher practice* mean value of 2.04 is *I teach students to become proficient in using tape diagrams to solve word problems*. Other items indicating higher degrees of change included:

- *My teaching of mathematics is aligned to the content outlined in the Common Core State Standards for Mathematics* (*change in teacher practice* mean value of .95).

Table 4.2

Descriptive Statistics for Teacher Practice

Think about your teaching practice and indicate the extent to which you agree with each statement below.	Prior to using *Eureka Math*		After using *Eureka Math*		Change in Teacher Practice	
	Mean	SD	Mean	SD	Mean	SD
My teaching of mathematics uses can be described as a balance between procedural skill (fluency), conceptual understanding and real-world application.	2.61	1.15	3.16	.98	.55	1.51
My teaching of mathematics is aligned to the content outlined in the Common Core State Standards for Mathematics.	2.51	1.20	3.46	.79	.95	1.43
I make a deliberate attempt to identify connections between previously covered content and new content when teaching new topics to my students.	3.07	1.09	3.46	.77	.39	1.18
Using a simple to complex approach, I use manipulatives and/or pictorial representations to introduce new concepts to students before moving to more abstract approaches to problem solving.	2.93	1.08	3.24	.94	.30	1.31
I incorporate fluency activities in my teaching in order for my students to master specific computational skills.	2.51	1.31	3.29	.89	.78	1.45

(Table 4.2 continued)

Think about your teaching practice and indicate the extent to which you agree with each statement below.	Prior to using *Eureka Math*		After using *Eureka Math*		Change in Teacher Practice	
I incorporate activities in lessons which require meaningful thinking and build understanding of concepts in mathematics.	2.91	1.01	3.31	.860	.40	1.21
I incorporate application problems in lessons which connect math concepts to the real-world.	2.54	1.15	3.44	.80	.89	1.38
I use questioning throughout the lesson to check for understanding	3.14	.96	3.57	.75	.43	1.15
I teach students strategies for doing mental math (doing math in their head) to build number sense in my students.	2.69	1.14	3.22	.90	.53	1.26
I teach students to become proficient in using tape diagrams to solve word problems.	1.14	1.37	3.18	.964	2.04	1.63
I use models with my students in order to build their number sense and to provide a foundation on which they can build computational strategies.	2.80	1.05	3.50	.77	.70	1.228
I use multiple ways of representing new concepts to my students.	2.76	1.17	3.42	.87	.65	1.35
Composite scores for teacher practice	2.63	.88	3.35	.70	.72	1.06

Note: The response scale for these items is a 5-point scale with values ranging from 0 to 4. 0 = Do Not Agree at All, 1 = Agree to a Minimal Extent, 2 = Agree to a Moderate Extent, 3 = Agree to a Good Extent, 4 = Agree to a Great Extent

- *I incorporate application problems in lessons which connect math concepts to the real-world* (*change in teacher practice* mean value of .89).
- *I incorporate fluency activities in my teaching in order for my students to master specific computational skills (change in teacher practice m*ean value of .78).

The item indicating the least amount of change with a *change in teacher practice* mean of .30 was *Using a simple to complex approach, I use manipulatives and/or pictorial representations to introduce new concepts to students before moving to more abstract approaches to problem solving*.

Using the two sets of values for each of the twelve items produced from the *teacher practice* scales, two composite scores were calculated for each teacher participating in the survey, one representing their teaching practice prior to using *Eureka Math* and one representing their current teaching practice. A Paired Sample t-Test was carried out using these composite scores, first checking that all assumptions were met. The results are shown in Table 4.3 below. There is evidence ($t = 7.532$, $p = 0.000$) that using *Eureka Math* has changed the practice of teachers in the sample significantly. This data shows that teaching practices have shifted to be more aligned with those reflected in the *Eureka Math* curriculum materials,

Table 4.3

Paired Sample t-Test Results Using Calculated Averages from the Teacher Practice Scale

	Mean	SD	t	Sig.
Teacher practice after	3.35	.70		
Teacher practice prior	2.63	.88		
TP after– TP prior	.72	1.06	7.53	.000

on average, by .72. Cohen's effect size value (*d* = .90) suggests a moderate to high practical significance. The confidence interval reveals that we are 95 percent confident that the interval from .53 to .91 contains the true mean difference.

The results provided Table 4.4 are further refined by school district and includes findings associated with the contrast school district. The means for *change in teacher practice* show teachers from District 2 and 3 reported teaching practices more aligned to the newly implemented curriculum than School District 1, but all three had means considerably higher than the contrast school district's mean for *change in teacher practice* at .13.

Table 4.4

District Level Means for Change in Teacher Practice

	School District 1	School District 2	School District 3	Contrast School District
Change in teacher practice	.54	.84	.81	.13

Teacher Changes: Qualitative Survey Results

The open-ended survey questions provided an opportunity for teachers to respond in their own words about changes to their teaching practice as well as changes to their beliefs about teaching and learning mathematics and changes to their knowledge and skills.

Changes in teacher beliefs. Using a constant comparative approach (Glaser & Strauss, 1967), responses to the three open-ended questions on the survey administered across districts were analyzed to understand teacher changes taking place as a result of curriculum use. The first question asked teachers about changes occurring in their beliefs about teaching and/or learning mathematics as a result of using *Eureka Math*. Two major categories emerged, the

first of which related to teacher beliefs around the use of instructional strategies associated with solving problems. Two subcategories were identified within this major theme. Some teachers reported that they now believe in using multiple strategies to teach students how to solve problems while others shared that they now see the value in using models when teaching problem solving. A teacher from District 3 stated, "The use of multiple strategies allows students with different visions to grab hold of a strategy that works for them" while a teacher from District 2 reported, "Since using EM, I see the value in teaching students using visual models, such as number bonds, tape diagrams, and area models." These subcategories are connected in that using tools such as models to solve problems requires the use of instructional strategies to implement them in the classroom.

The second major category to emerge around changes in beliefs relates to the value of understanding mathematics conceptually in a more profound way. Teachers expressed this many times as the importance of teaching the *why* so that students are not merely memorizing procedures but developing conceptual understanding around a given topic. The following quote came from a teacher interviewed in District 1:

> I developed a deeper belief in teaching the "why?' instead of just teaching "how" to do the math. I see that my students have developed deep understanding of concepts that help them a lot when they are introduced to new material.

Teachers also conveyed the value they saw in students gaining a better or deeper understanding of mathematics. A teacher from District 2 responded to this question with the following response: "We should be teaching fewer skills at a greater depth (like we are now) than the plethora of skills with little to no depth like we have for so many years." Other categories emerged around this question related to changes in teacher beliefs but with

considerably less frequency. These categories included: the use of specific pedagogical approaches (e.g., group work, more use of discussion), use of fluency, incorporation of application problems, and belief in what students are capable of.

Changes in teacher knowledge. The second open-ended question related to the knowledges/skills teachers have gained through their use of the curriculum. A single, prominent category emerged across all three districts implementing *Eureka Math.* Teachers overwhelmingly reported acquiring knowledge and skills around instructional strategies related to problem solving and the models associated with those strategies. A District 2 teacher reported the following, "I have gained a different way for teaching difficult concepts, in particular, fractions. I love the use of models and pictures to teach those often times extremely difficult concepts for children." Developing a deeper understanding of mathematics was also reported frequently. Other categories which emerged but at a much lower rate of occurrence included knowledge related to fluency, assessment, application problems, and specific pedagogical approaches.

Changes in teacher practices. The final open-ended question asked teachers to report the changes that have occurred in their practice since using the new curriculum. The two primary changes identified by teachers using *Eureka Math* included shifts in instructional strategies/models related to problem solving (e.g., teaching multiple strategies, using visual models) and shifts in general pedagogical instructional approaches (e.g., organization of their lessons, amount of student driven instruction, balance of rigor, questioning techniques). A teacher from District 3 explained the shift in her practice as follows:

> The changes in my practice which occurred as a result of using Eureka Math is a more open minded way of solving problems. I have learned various ways of deriving an answer instead

> of thinking that there is only 1 strategy that could be used and teaching only the strategy that I was comfortable with.

Another teacher reported, “I let students talk more with each other before I ask for an answer.” Other changes which surfaced in teacher responses but at a lower rate of frequency included more focus on conceptual understanding, changes related to fluency, application problems, assessment as well as changes in their students (e.g., attitude, knowledge, results).

It should be noted that for each of the three open-ended survey questions, the major themes were the same across all three districts indicating a level of consistency in the types of changes teachers experienced. There were a small group of teachers from each district which reported no changes as a result of their curriculum use. A few teachers also provided general positive or negative feedback about their experience with the curriculum rather than answering the questions posed.

Contrast school district responses. In analyzing the open-ended responses from the contrast school district which had 23 teachers participate, there were no dominant themes which emerged for the question related to changes in beliefs about teaching and learning mathematics. None of the following categories included more than three responses: instructional strategies related to problem solving, pedagogical instructional strategies, use of writing in mathematics, word problems, rigor and no changes. A few teachers expressed that they either used the curriculum as a supplement or supplemented with other resources. One teacher reported that they stopped using the curriculum halfway through the first year and started using *Eureka Math* and have been using *Eureka Math* since that time. This brings into

question the level of fidelity of the implementation of the new curriculum in at least some schools in the contrast district.

Responses to the second question about change in knowledge and skills revealed three main categories: pedagogical instructional strategies, instructional strategies related to problem solving and no changes. The category with the most responses was no changes. The third open-ended question had responses from two primary categories which were pedagogical instructional strategies and no changes. One teacher indicated that changes had occurred in her practice but that they were attributed to other resources rather than the curriculum the district had adopted. These results are in rather sharp contrast to the districts implementing *Eureka Math*.

Teacher Changes: Interpretation of Results

With the data collected during phase one of the study indicating evidence of teacher change, interviews during phase two were conducted in effort to gain insight into the teacher change process. Interviews provided an opportunity for teachers to describe changes around beliefs, knowledge, and practice at length and to discuss how decisions related to changes in their practice came about. Teachers were also asked about instances when they decided not to make changes suggested by the curriculum.

The analyses of the responses to the three open-ended survey questions revealed links among the major themes which emerged for each question. For all three questions, the most frequent response by teachers involved changes in the area of problem solving instructional strategies and their associated models, but there are other interesting connections. It was evident from the interviews and from the responses to the open-ended questions that districts

mandated implementation of the curriculum, and teachers felt compelled to honor this directive. As teachers moved through the implementation process, it was necessary to acquire the knowledge and skills they lacked in order to enact the curriculum. As the previously mentioned results show (summary provided in Table 4.5), most of the new learning centered around the problem solving instructional strategies and associated models in the curriculum materials with which teachers were unfamiliar. This category also emerged as a major theme for the questions related to changes in beliefs and teacher practice. The conceptual understanding of mathematics theme also emerged across all three questions related to teacher changes but to varying degrees. Teachers reported gaining a better understanding of mathematics primarily from a conceptual standpoint and also reported that

Table 4.5

Themes Emerging from Open-ended Survey Questions

	Change in Beliefs	Change in Knowledge	Change in Practice
Instructional strategies related to problem solving	Major Theme	Major Theme	Major Theme
Conceptual understanding of mathematics	Major Theme	Moderate Theme	Minor Theme
Pedagogical instructional approaches	Minor Theme	Minor Theme	Major Theme
Fluency	Minor Theme	Minor Theme	Minor Theme
Application problems	Minor Theme	Minor Theme	Minor Theme
Student outcomes	Minor Theme	---	Minor Theme
Assessment	---	Minor Theme	Minor Theme
No change	Minor Theme	Minor Theme	Minor Theme

they now saw the benefit of conceptual understanding, teaching their students the *why* behind rote procedures. Teachers also reported, but to a lesser degree, more of a focus on conceptual understanding in their teaching, but it should be noted that many of the new problem solving strategies teachers reported using are rooted in conceptual understanding.

Pedagogical instructional strategies emerged as a major theme for change in practice while it appeared as only a minor theme for changes in beliefs and knowledge. If teachers implement the curriculum with fidelity, it would stand to reason that change would occur from a pedagogical standpoint from their previous practice but may not necessarily result in dramatic changes in knowledge or beliefs. As seen in Table 4.5, all themes were duplicated for at least two questions related to teacher change while some occurred in all three.

Based on these findings from the open-ended survey responses and information teachers provided during interviews, it appears that using the curriculum in year one was a matter of abiding by the district mandate regardless of how they felt about implementing the curriculum. After obtaining the necessary skills and knowledge and enacting the curriculum, many teachers were convinced of the value in their changes as they increased their own understanding of mathematics and experienced positive results in the classroom with their students. These shifts in teacher beliefs about teaching and learning mathematics appear to have led to enduring changes in their classroom practice.

Several examples surfaced during interviews with teachers which support this line of reasoning. When asked what is different about her teaching practice, one teacher stated the following, "I do teach multiplication and division differently. I never taught it using a Place Value Chart." "Now", she states, "we use a Place Value Chart for everything," but when she

first saw it in the curriculum she “thought it was a little crazy and time consuming.” She now believes its use gives students a good foundation for understanding concepts associated with multiplication and division and serves as a tool her students refer back to if they get stuck when solving problems. Another teacher shared her experience as she implemented the curriculum.

> As a math teacher of ten years, I have learned more about math in two years than I’ve ever known in my life, which is scary now to me than it was two years ago when I thought I knew what I needed to know to teach 5th grade math. … At first I was an ELA teacher and somewhere along the way… I ended up with math, and I developed a love for it over the years, but I still didn’t have a great understanding of the math.

She went on to explain that she shares her knew understanding of mathematics with her students by no longer teaching skills in isolation and teaches “the math” behind it so students understand why procedural methods work. One of her aha moments was around the concept of decimal place value, rounding to the nearest tenth. Previously she had taught ‘5 or more raise the score’, but the curriculum teaches this concept on a vertical number line. “Twenty-five and eight tenths (25.8), seeing it as 258 tenths on the number line…that lesson blew me away. I never in my life saw 25 and 8 tenths as 258 tenths. I always saw it as 25 plus 8 tenths of another whole. That was really like wow!” These examples reveal what may be a common trajectory teachers share on the path to lasting change in their practice.

This teacher also shared that she worked in a nearby district when *Eureka Math* first emerged in the marketplace. At that time, teachers in her district were given the option of implementing the curriculum and she opted not to use it because “it scared” her. “The first module was very intimidating. I didn’t understand it as a teacher, and so I didn’t feel like I could teach it a whole new way.” She regrets that decision now.

During interviews, teachers were asked to provide illustrating instances when the curriculum called for doing something differently in terms of their classroom practice, but they chose not to make a change. They were asked what contributed to those decisions. This prompt led to teacher responses which largely pointed to unsuccessful student outcomes, using words such as *struggled* and *confused*, but responses also included topics around conflicting demands placed on teachers. One teacher explained, “When we did elapsed time on a number line, last year my kids struggled with that so much.” She went on to explain how time charts had been used previously and described how she had taught this method afterwards, even though it was not in the curriculum. She allowed students to use their preferred method. Two other responses to this interview prompt are as follows:

> Sometimes they’ll get confused on the number line [with fractions], and I didn’t want to confuse them even more. I did go back to the number line after they understood better and tried to teach them that way, but I found most of them were just totally confused with the number line.
>
> The concept development is everything. In fact, that’s probably the strongest component [of the curriculum]. They aren’t all that way, but I do feel like sometimes that’s probably a foundational thing. I don’t teach some of the lessons in the Concept Development the way it’s presented because I feel like I would have to go so far back to teach them this that they should have been taught in first, then this in second, then this in third, and this in fourth to get to this fifth grade skill….I kind of probably almost teach it the older way, not very often and I can’t think of an example, but I think they sometimes don’t have the foundation to understand the way it’s presented in the fifth grade curriculum. … We were spending two to three days on one lesson. We were very behind last year and testing was a lot earlier, in March. I had only gotten completely through Module 3. I couldn’t take the time needed to establish the Concept Development the way it was intended.

In addition to student outcomes, it appears that the demands associated with state testing may be a second reason teachers do not make changes to their practice which are called for by the curriculum.

A closer look at the results from the *teacher practice* scales of the survey revealed how they compare with the qualitative data collected from the open-ended questions and teacher interviews. On average, teachers reported that prior to using *Eureka Math* they *agreed to a moderate extent* (2.63) that their teaching practices were reflected in the items found in the survey's *teacher practice* scale. In contrast, teachers reported that after using *Eureka Math* they *agreed to a good extent* (3.35) that their practices aligned with those described in the same survey items. The Paired Sample t-Test performed to compare the composite scores of participants for teacher practice prior to and after using *Eureka Math* provides rather convincing evidence that the implementation and use of new curriculum materials changed the practice of teachers in the sample and was confirmed by the analysis of the qualitative data collected.

Analyzing the results of the teacher practice scale revealed more information about the areas where teachers experienced change. The survey item related to use of tape diagrams (*I teach students to become proficient in using tape diagrams to solve word problems.)* by far represented the largest shift in teacher practice with a *change in practice* mean score of 2.04. This was the only model specifically called out in the survey items and was targeted because of its frequent use in *Eureka Math* across grades 3 through 5 and because it was a model that many teachers were likely to be unfamiliar with prior to using this curriculum. These results confirm those revealed by the analysis of the qualitative data from the open-ended questions and teacher interviews, which identified problem solving instructional strategies and their associated models as the most prominent category across all three questions related to teacher change.

Mean values on every item of the *teacher practice* scale showed an increase after curriculum use. It is clear that some items—such as those related to using questioning to check for understanding, making connections between previously covered and new content, and using models to build number sense and provide a foundation for computational strategies—were more prominently reflected in teachers' practices prior to implementing *Eureka Math* when compared to other types of activities detailed in the scale items. It should be noted that this prior level of use did not preclude teachers from expanding their use of such practices. The items describing these practices had three of the highest mean values reported after using *Eureka Math* curriculum materials.

The contrast school district's *change in teacher practice* mean value of .13 is considerably lower than those of the three districts using *Eureka Math*. The results of the analysis of the open-ended responses from teachers in the contrast district were quite different from the other three districts and included a much higher percentage of responses indicating that no change had occurred. Furthermore, the same level of agreement among teachers about the changes they experienced did not exist within the contrast group. This distinction leads to several interesting conclusions. First, shifts in teaching practices cannot alone be attributed to mathematics standards changing with the release and adoption of the CCSSM. If this were the case, one would expect to see similar results across districts regardless of the curriculum adopted and implemented. Secondly, different mathematics curriculum materials do not appear to impact teacher practice in the same way. The items included on the *teacher practice* scale were written to reflect teaching practices associated with *Eureka Math*, but they

are also associated with the instructional shifts of the CCSSM and might expected to be reflected in other standards based reform-oriented curriculum materials.

These findings make it clear that the use of *Eureka Math* has shaped the professional practice of teachers in enduring ways. Findings also lend support to the idea that all curriculum materials do not shape teacher practice in the same way and that some may be more effective than others.

How Teachers Use *Eureka Math* Curriculum Materials

Results from survey items related to curriculum use are presented in Table 4.6. Teachers reported the extent to which they interacted with the curriculum materials in particular ways. On average, participants reporting engaging in the types of curriculum use outlined in the survey items *to a good extent*. The mean values of the individual survey items for *curriculum use* are fairly consistent with a range from 2.92 to 3.38. With all three districts having used *Eureka Math* for up to three years and with appropriate support from district and school level leaders to ensure fidelity of implementation, it is not particularly surprising that teachers reported engaging in the types of curriculum use outlined in the survey items. The item having the highest mean value on the *curriculum use* portion of the survey was *Studying the lessons to build your own understanding of new ways to teach specific mathematics content*. This finding is connected to and validated by the results detailed for the first research question which indicated teachers gained knowledge primarily in the area of instructional strategies related to problem solving and to the models associated with those strategies.

Phase two of the study provided an opportunity for teachers to talk about their use of curriculum materials in their own words and to describe how their use of the materials may

Table 4.6

Descriptive Statistics for Curriculum Use

To what extent have you engaged in the following activities with *Eureka Math* curriculum materials:	Mean	SD
Studying Module Overviews at your grade level in an effort to understand how the mathematics progresses through the year.	2.92	1.11
Examining the general outline of activities taking place in a lesson for planning purposes.	3.22	.92
Analyzing teaching sequences in a lesson to determine how to make adjustments necessary to meet student needs.	3.15	.98
Studying a segment of problems (e.g., Exit Tickets, Problems Sets, etc.) in the lessons to see the trajectory of the mathematics students are expected to be able to do.	3.30	.84
Studying the lessons to build your own understanding of new ways to teach specific mathematics content.	3.38	.82
Studying Topic Overviews in a module to understand how the content is connected across topics.	3.13	.96
Examining the Teacher/Student sample dialogue in the lessons to formulate questions to be used while teaching the lesson.	3.01	.98
Analyzing the work of your students to determine how an upcoming lesson should be adapted to meet student needs.	3.21	.93
Studying lessons in a topic to understand how the mathematics progresses through the topic.	3.27	.81
Composite scores for curriculum use	3.18	.79

Note: The response scale for these items is a 5-point scale with values ranging from 0 to 4 (0 = Not at all, 1 = To a Minimal Extent, 2 = To a Moderate Extent, 3 = To a Good Extent, 4 = To a Great Extent).

have changed across multiple years of implementation. Interviews with teachers and leaders revealed that ongoing formal professional development sessions provided by the districts introduced many of the new strategies to teachers. However, much of their new learning was gained through sometimes intense independent study of the Concept Development portion of the lessons and included working through the Problem Sets themselves. These efforts were necessary so that teachers were able to understand the strategy prior to instructing their students in the problem solving method. Aside from teachers making very general references during interviews about curriculum use such as reading or studying the lessons or overviews, studying specific lesson components to build their understanding of new ways to solve problems was the only activity mentioned which was more specific in nature.

When asked about the differences in their use of the curriculum over time during the interviews, most teachers reported that in the first year of implementation they adhered very closely to what was in the curriculum materials because they lacked familiarity with the content. Exposure to the materials and the experience of teaching it to their students in year one provided teachers with valuable information upon which they could then draw. One of the teachers interviewed had just completed her first year of implementation of the curriculum. She was returning to the math classroom after a period of time away, and she indicated that she followed the curriculum very close because of her unfamiliarity with the materials and not because she was instructed to do so at the school or district level. Year one seems to be a year where teachers focus on the details of the curriculum and acquire the bulk of the new knowledge and skills out of necessity to enact the curriculum.

Nearly every teacher interviewed made reference to difficulty with pacing during year one and expressed being able to cover significantly more in year two. As one teacher stated, "We weren't good at managing time the first year and probably didn't do the last two modules. It's gotten better." Another teacher indicated that she "learned through teaching it in year one where to focus with the time available – there's more modification now." Once teachers had increased familiarity with the content of the curriculum, the experience of enacting it, and a better understanding of the big ideas of the curriculum, they were able to make decisions about coverage more strategically and move more quickly through the content. As teachers continued to use the materials, trust in the curriculum grew. The following quotes from teacher interviews support these findings.

> Basically since it was my first year doing *Eureka Math*, I started with every direction [the curriculum materials] told me because I needed to understand the whole process. I had to study it ahead of time. I had to really prep myself ahead of time so I understood the way they wanted me to present it to the students.
>
> That first year I was stressed. I couldn't believe they were making our kids do some of these things, but after the first year, I understood why they were making them do certain things. So, it made more sense after that. Like distributive property in 3rd grade, I couldn't figure out why we were making them break apart these numbers 9 x 7. Why break apart 9 into 5 and 4 when you can just memorize 9 x 7, but it was giving them facts that they knew already to learn the principle so that way they could use it on bigger numbers. I didn't really get that in the beginning. I was like, why are we going through all of this just to get to 9 x 7. When all of the pieces fall together, you understand.
>
> [In the second year], I wasn't as dependent of the teacher module. I kind of made it my own, and I knew where I was going in the end. Once I got familiar with the program, it was easier.

It should be noted that the contrast district did not complete the portion of the survey related to curriculum use. These survey items were written with language directly related to

the components of *Eureka Math.* Without considerable revamping, these items were not well aligned to those found in the curriculum the contrast district had adopted.

Factors Contributing to Change in Teacher Practice

Results from survey items related to PD program coherence are presented in Table 4.7. The survey revealed that teachers on average believed that the PD program was coherent *to a*

Table 4.7

Descriptive Statistics for Coherence of the PD Program

During the time you've used *Eureka Math* curriculum materials, please indicate the extent to which professional development activities organized by your school or district:	Mean	SD
Have been aligned with the school's mathematics curriculum (*Eureka Math*).	3.28	.95
Have been aligned with the mathematics standards adopted by your school, district and state.	3.33	.92
Have been aligned with state standardized assessments in mathematics your students are administered.	3.15	1.07
Have been consistent with your own goals, knowledge, and beliefs as a teacher.	2.97	1.14
Have been consistent with the work you do in the classroom.	3.09	1.08
Have been consistent across the professional development program, meaning activities are part of an integrated program of teacher learning with activities related to each other.	2.94	1.14
Composite scores for coherence of the PD program	3.12	.92

Note: The response scale for these items is a 5-point scale with values ranging from 0 to 4 (0 = Not at all, 1 = To a Minimal Extent, 2 = To a Moderate Extent, 3 = To a Good Extent, 4 = To a Great Extent).

good extent (3.12). Participating teachers appear to view their professional development experiences as generally well-aligned to *Eureka Math*, the standards, state standardized assessments, the work they do in the classroom, and their own goals, knowledge and beliefs as teachers. Results also appear to support a belief that such activities are well integrated into a cohesive program. The mean values for *coherence of the PD program* are fairly consistent across the individual survey items with mean values ranging from 2.94 to 3.33. Teachers reported alignment of the PD program as strongest with the *Eureka Math* curriculum and school, district and state standards.

Results from survey items related to teachers' opportunities to collaborate are presented in Table 4.8. Teachers reported the extent to which they had occasions to come together with their colleagues to participate in the types of activities represented in the survey items as *moderate to good*, on average (2.43). *Plan mathematics instruction with other teachers* is the activity which teacher reported having the opportunity to engage in the least. Teachers collaborating about student work, instructional strategies and the mathematics curriculum ranked highest on the survey. The mean values of the individual survey items for *opportunities to collaborate* are fairly consistent with a range of 2.13 to 2.59.

The results provided in Table 4.9 show mean values refined by school district and include findings associated with the contrast school district. Teacher perception of the coherence of the PD program did not differ much among the teachers participating from the four school districts; however, the contrast school district teachers, on average, reported having more opportunities to collaborate than those in the three districts implementing *Eureka Math*.

Table 4.8

Descriptive Statistics for Opportunities to Collaborate

During the time you've used *Eureka Math* curriculum materials, please indicate the extent to which you've had the opportunity to engage in the following activities at your school or district:	Mean	SD
Collaboratively examine and discuss student work in mathematics.	2.58	1.17
Work with colleagues on instructional strategies related to mathematics.	2.59	1.22
Meet with other teachers to have meaningful discussions about the mathematics curriculum.	2.54	1.23
Meet with other teachers and work math problems from the curriculum.	2.33	1.26
Plan mathematics instruction with other teachers.	2.13	1.30
Discuss implementing ideas from professional development training into your classrooms.	2.41	1.34
Composite scores for opportunities to collaborate	2.43	1.13

Note: The response scale for these items is a 5-point scale with values ranging from 0 to 4 (0 = Not at all, 1 = To a Minimal Extent, 2 = To a Moderate Extent, 3 = To a Good Extent, 4 = To a Great Extent).

Table 4.9

District Level Means for Coherence of the PD Program and Opportunities to Collaborate

	School District 1 Means	School District 2 Means	School District 3 Means	Contrast School District Means
Years teaching	14.73	12.89	15.05	13.48
Coherence of the PD program	3.03	3.00	3.41	3.11
Opportunities to collaborate	2.51	2.28	2.51	3.17

Note: The response scale for these items is a 5-point scale with values ranging from 0 to 4 (0 = Not at all, 1 = To a Minimal Extent, 2 = To a Moderate Extent, 3 = To a Good Extent, 4 = To a Great Extent).

Pearson correlations were calculated to determine relationships between c*hange in teacher practice* and *curriculum use*, o*pportunities to collaborate, coherence of the PD program* and *teaching experience*. The resulting correlation coefficients are presented in Table 4.10. Results for this study reveal that *change in teacher practice* is significantly, positively correlated with *curriculum use*, *opportunities to collaborate* and *coherence of the PD program*. With a correlation coefficient of .442, *coherence of the PD program* is most strongly related to c*hange in teacher practice* with a moderate degree of correlation. *Years teaching* is negatively

Table 4.10

Pearson Correlations and Results from Regression Analysis

	Correlations with Change in Teacher Practice (Sig.)	b	β
Curriculum use	.289** (.001)		
Opportunities to collaborate	.309** (.000)		
Coherence of the PD program	.444**(.000)	.532	.457**
Years teaching	-.174* (.031)	-.024	-.202*

Significance: *p < .05, **p < .01

correlated with *change in teacher practice* but the relationship is considerably weaker than its relationship with the other factors.

A stepwise multiple regression analysis was conducted in SPSS with all four predictor variables producing an $R^2 = .23$, $F(1, 112) = 5.998$, $p < .05$. All assumptions were met except for the assumption of homoscedasticity. Slight heteroscedasticity was evident, but according to Tabachnick and Fidell (1996), this has little effect on significance tests. As seen in Table 4.10,

coherence of the PD program had a significant positive regression weight (.457) , indicating teachers who viewed more alignment between the PD program and the other aspects of their teaching practice (i.e., state standardized tests, curriculum, what takes place in the classroom, etc.) were expected to change their teaching practices to a greater extent. The number of years a teacher had taught has a significant negative weight (-.202), indicating that after accounting for *coherence of the PD program*, those teachers with more classroom experience were expected to experience less change in their practice. *Curriculum use* and *opportunities to collaborate* did not contribute to the multiple regression model.

The results of the stepwise multiple regression analysis revealed that approximately 23% of the variability in teacher practice changes can be explained by teachers' perceptions of PD program coherence and the number of years they have been teaching. While coherence explained more of the variability than the other factors investigated, there is still a large portion of the variability in *change in teacher practice* which is not explained by the factors included in this study.

One interesting finding was the lack of a strong relationship between *change in teacher practice* and *opportunities to collaborate*. During phase two of the study, teachers and district leaders were asked opportunities for teacher collaboration, the district's capacity to provide time for teachers to collaborate, and any structures in place to support this type of teacher interaction. In addition, questions were asked about the types of PD activities teachers participated in during curriculum implementation and their perceptions of the PD program's coherence.

According to teachers interviewed, they were not given much time to collaborate with other teachers, and when they were, they were generally not engaging in the type of activities included on the survey. All the teachers I met with indicated that they had professional learning communities (PLCs) at their schools, but the typical tasks engaged in during meetings were largely logistical type tasks not directly related to curriculum implementation. Teachers in the contrast school district reported considerably more opportunities to collaborate with one another but failed to show much in the way of change in teacher practice. Because the contrast school district did not participate in phase two of the study, many questions remain unanswered about their implementation as well as the nature of the collaboration among teachers. Perhaps the extent of teachers' independent study of the curriculum or attendance at formal professional development sessions might have revealed stronger connections to changes in classroom practice as these factors were those teachers identified as influential during interviews.

Reliability and Validity

In this study, scales were developed to measure *curriculum use*, *change in teacher practice, opportunities to collaborate* and *coherence of the PD program*. Each of the scales contained between six and twelve items which were averaged to obtain composite scores for each participant. A factor analysis was conducted on each scale using principle components analysis to establish construct validity, and a calculation of Cronbach's Alpha was used to determine reliability. A summary of these results is reported in Table 4.11.

Credibility of the qualitative results was demonstrated using two triangulation techniques, data source and methodological. Interviews were conducted with both teachers

Table 4.11

Results of Factor Analysis and Reliability Ratings

	No. of Questions	No. of Factors	Eigenvalues	% of Variance	Cronbach's Alpha
Curriculum use	9	1	6.592	73.25	.95
Opportunities to collaborate	6	1	4.928	82.14	.96
Coherence of the PD program	6	1	4.638	77.30	.94
Change in teacher practice	12	1	7.554	62.95	.94

and districts leaders in order to get perspectives from two different groups or sources within each district. Employing both a variety of qualitative and quantitative methods in the study allowed for checking the consistency of findings generated by the different data collection methods. Details provided around the sampling process, participants, curriculum, and context of the study assisted in establishing transferability. Dependability and confirmability were achieved by forming an audit trail as data was collected and analyzed. Connecting the findings to the existing literature assisted in establishing confirmability.

CHAPTER 5
DISCUSSION, LIMITATIONS, IMPLICATIONS AND RECOMMENDATIONS

Overview of the study

This chapter provides a discussion of the major findings of this study in the context of existing literature. Comments on limitations of the study, implications of its findings for professional practice and curriculum developers, and recommendations for future research are also provided.

There is mounting evidence that much professional development, even when it meets the venerable criteria, has little effect on student achievement (Harris & Sass, 2011; Jacob & McGovern, 2015). Despite such results, the need to identify the type of support that develops teachers professionally still exists. The failure of traditional forms of PD to produce results leads us to explore alternative approaches. We now have some evidence that professional development linked to high-quality curriculum materials may be what is needed to improve teachers (Collopy, 2003; Frykhom, 2005; Li et al., 2012; Noh & Webb, 2015).

The purpose of this study was to provide insight about how professional growth of upper elementary teachers is linked to the implementation of standards based curriculum materials and the resulting changes in teacher beliefs, knowledge, and classroom practice. The study sought to compare the influences of four factors on *change in teacher practice*: *coherence of the PD program*, *opportunities to collaborate*, *curriculum use*, and *teaching experience*. The body of existing literature informed the focus and design of this research, and much like other studies, aimed to find potential solutions for improving instructional practices (and ultimately, student learning). In this mixed method sequential explanatory study,

qualitative data from open-ended survey questions and interviews together with quantitative data from Likert-scale survey items allowed for triangulation of data collected. Below, the major findings are discussed in the context of the existing literature.

Discussion

The Impact of Curriculum Use on Teachers and Their Practice

This study has provided clear evidence that curriculum materials can serve as a teacher development tool and an agent of change in teacher practice. The vast majority of teachers using *Eureka Math* reported changes to their beliefs, knowledge, and classroom practice as a result of curriculum use. (Admittedly, there were a small number of teachers who reported no change in these areas). These findings are consistent with those of several studies on this topic. A study by Noh and Webb (2015) noted the link between increased teacher subject matter knowledge and their experience teaching with educative curriculum materials. Li et al. (2012) examined the influence of curriculum reform on teachers' perceived instructional practices and found that those teachers who used reform-based curriculum were more likely than teachers using conventional curriculum to report practices advocated by the reform. This study's findings are consistent with Collopy's (2003) case study, which found curriculum materials designed to foster teacher learning in the areas of pedagogy and mathematics can be effective.

Model of Teacher Change. Teacher responses to the open-ended survey questions uncovered connections across changes in teacher beliefs, knowledge, and practices. Teacher interviews revealed commonalities in the teacher change process as a result of teachers' curriculum use. The adoption of *Eureka Math* by districts and their mandate on teachers to implement it acted as the impetus for teachers to alter instruction. In order for teachers to

enact the new curriculum, it was necessary for them to acquire new learning. This new learning occurred through various modes of professional development centered on curriculum implementation and provided teachers with not only the knowledge and skills necessary to teach the new methods but oftentimes a deeper understanding of mathematics. Implementation of new instructional approaches and the positive results thereby obtained, led teachers to alter their beliefs about teaching and learning mathematics. After three years of curriculum us, many teachers made enduring changes in their practices.

These findings are consistent with Guskey's model of teacher change (2002), which places an emphasis on successful implementation of new teacher practices. He suggests that just because a teacher tries out a new instructional strategy, it does not guarantee its continued use in the classroom. When evidence is produced that confirms a new practice has led to successful student learning outcomes, a teacher's attitude or beliefs towards that method or approach is impacted in a significant way. His theory emphasizes the power the enacted curriculum may have on shaping teachers professionally.

Ma (1999) states that teacher and student learning of mathematics are interconnected and must occur simultaneously, and that given the right motivation and opportunity, teachers improve their subject matter knowledge when they teach it. The findings of the present study support Ma's claim. The interconnectedness of teacher change in the areas of beliefs, knowledge, and practice prompted by curriculum use supports the idea that curriculum materials have the capacity to shape the beliefs and understandings of teachers (Blumenfeld et al., 1994; Guskey, 1988; Remillard, 2000).

Curriculum Choice. It appears that curriculum choice matters. The results of the analysis of the *teacher practice* scale on the survey and the responses to the open-ended questions were markedly different for the districts implementing *Eureka Math* when compared with those of the contrast school district. Agodini and Harris (2011) compared four different math curricula, showing that curriculum choices make a difference when it comes to student achievement. Although the current study did not focus on student achievement, but rather the precursor, change in teacher practice, there is increasing evidence that curricula have differential effects and that districts should make informed decisions when making these choices.

Remillard, Harris, and Agodini (2014) explored the strongly differing design features of four sets of curriculum materials. They found that there were substantially different types of opportunities to learn across the materials and that a number of elements could be consequential in shaping instruction and the learning which results. The design features studied included mathematical emphasis, instructional approach, and support for teachers.

Although this study focused on the impact of curriculum materials on teachers, the state department of education's website provides state standardized student achievement data for participating districts. Table 5.1 details the changes in the percentage of students in grades 3–5 scoring *Mastery* or above on state standardized tests in mathematics between 2014 and 2016. Districts implementing *Eureka Math* increased the number of students scoring *Mastery* or above from 2014 to 2016 at a higher rate than both the contrast district and the state. There are numerous factors which could have influenced student test scores, but the data indicates that teacher changes may have influenced student learning.

Table 5.1

Percent of Students Scoring Mastery or Above on State Tests in Mathematics

	District 1	District 2	District 3	Contrast District	State Average
Grade 3 change from 2014 to 2016	18%	19%	27%	16%	12%
Grade 4 change from 2014 to 2016	10%	9%	17%	0%	0%
Grade 5 change from 2014 to 2016	21%	21%	21%	15%	12%
Total change across grades from 2014 to 2016	49%	49%	65%	31%	24%

Curriculum Use

Teacher responses from this study indicate that they follow the mandates of their districts, at least when it comes to the implementation of curriculum despite their initial feelings about the decision. Given the option of whether or not to use a new curriculum, many teachers may decline, especially those who are uncomfortable with the change.

When considering curriculum as a professional development tool, it must be recognized that curriculum use appears to occur in stages during the implementation process. Teachers discussed the challenges of implementation in year one during teacher interviews. This aligns with existing research findings concerning anxiety and confusion during the initial implementation of a new curricular program (Guskey, 2002). During year one of

implementation, teachers were busy trying to absorb the structure, components, and strategies of the new curriculum so that they were able to enact the curriculum with some degree of fidelity in their classrooms. There were varying levels of uncertainty, lack of confidence, and stress associated with this phase, and teachers generally closely adhered to the material the way it is presented in the teacher manual. These findings are consistent with Drake and Sherin's (2009) conclusion that a teacher's curriculum strategy at least during the first year of implementation is somewhat stable.

Once teachers got past the initial exposure to the materials and had the experience of enacting the curriculum with students, they felt more equipped to make adjustments and had more of a grasp on how and why the curriculum unfolds the way it does. They were able to see the bigger picture and began to trust the progression of the content and the approaches to problem solving presented in the curriculum. With more opportunities to enact the curriculum, teachers' trust in the curriculum continued to grow as did their skill in using it. Drake and Sherin (2009) also found that continued engagement with curriculum materials can result in increased trust which can further shape the way teachers use curriculum materials.

Factors Influencing Change in Teacher Practice

Coherence. Coherence appears to be a strong factor which influences the success of teacher development programs and has received increased attention by the educational research community (Allen & Penuel, 2015; Firestone, Mangin, Martinez & Polovsky, 2005; Lindsey, 2010; Leo & Coggshall, 2013; Penuel et al., 2007). The current study supports past findings concerning the importance of coherence, and the role perceived coherence plays as a predictor of change in teacher practice.

Penuel et al. (2007) also reported teacher perceptions about the coherence of their PD experiences as a significant positive predictor of teacher change, and Firestone et. Al (2005) found PD with the most coherent focus had the greatest teacher-reported impact on classroom practice. McCaffrey et al.'s (2001) study involved a district implementing a systemic reform in STEM areas with all teachers receiving the same reform-aligned professional development. Findings revealed that of two groups of teachers in the same district, one implementing a reform-based curriculum and the other a traditional curriculum, those teachers using curriculum materials coherent with the reform were impacted to a greater degree as was student learning. More recently, Allen and Penuel (2015) noted the influence that teachers' perceptions of coherence had on the use of newly acquired learning and resources from PD experiences.

Other factors. The findings of Collopy (2003) and Li et al. (2012) suggest that teachers who are more experienced, and perhaps more comfortable with their knowledge of mathematics, are often less apt to make changes to their practices as a result of curriculum use. This finding corroborates those of the present study where the number of years of teaching experience emerged as a significant negative predictor of change in teacher practice.

Drake and Sherin (2009) state that teachers need continued opportunities to study lessons in meaningful ways with their colleagues in order to experience the full potential curriculum materials have to offer. The present study did not reveal an important relationship between teacher collaboration and the extent to which curriculum materials changed their practice as o*pportunities to collaborate* in this study was not shown to be a predictor of *change in practice*. Although in Li et al.'s (2012) study the teacher reported reform-based instructional

practices were positively correlated with teachers' perceptions around collaboration, teachers implementing both the reform and conventional curriculum reported about the same amount of opportunities to collaborate with colleagues. Penuel and Allen (2015) suggest focusing teacher collaboration around reconciling issues of perceived incoherence. Perhaps with this focus, collaboration may prove to be more influential on change in teacher practice.

Limitations

Participation was restricted to mathematics teachers in grades 3–5. It is unclear if the types of changes reported by teachers in our sample would be the same as teachers in other grade bands. The three districts implementing *Eureka Math* which participated in this study were from the same southern state, in close proximity to one another, and shared similarities in implementation of the curriculum due to their close collaboration; therefore, these findings cannot be generalized to all settings.

Another limitation of this study was the lack of qualitative data collected on the contrast school district. Ideally, there would have been more information about the district's implementation of the new curriculum, the types of support teachers were provided from a professional development standpoint, and teachers' use of curriculum materials. Due to this limitation, conclusions drawn between the districts implementing *Eureka Math* and the contrast district are considered tentative.

Although the present study revealed key findings about the way teachers in the sample used *Eureka Math* and how that use ultimately impacted their practice, it did not analyze student learning outcomes. Did the changes which took place in teachers' instruction also result in changes in student learning? There are indications from the data that this was the

case, but there was no formal analysis of student learning as this was not the focus of this particular study. Additionally, the data collected in this study relied heavily on teacher report. The lack of teacher observations to confirm what teachers reported is also viewed as a limitation of the study. Due to the timing of the data collection process, conducting such observations was not possible.

Implications

Implication for Professional Practice

Districts should make informed decisions when making curricular choices as all materials do not have the same payoffs in terms of teacher and student learning. Districts should seek out materials that are of high quality and educative in nature—those with built in support for teacher learning. Additionally, districts should strongly consider implementation as a mandate as this seems to serve as a stimulus for enacting curriculum and teacher participation in various modes of professional development. The first year of curriculum implementation seems to be the most challenging and the time when teachers need the most support from the school and district level. Those in charge of implementation should prepare teachers for what to expect during year one and put support structures in place to assist with challenges such as anxiety and pacing. School and district leaders should take the necessary steps to align the many demands placed on teachers by various reform agendas so that teachers perceive coherence rather than conflict in the goals set for them in the classroom. Those in charge of professional development should highlight how expectations from different agendas intersect and can be achieved simultaneously.

Implications for Curriculum Developers

The findings of this study indicated that teachers acquired much of their new learning around problem solving instructional strategies through the study of specific lesson components. As curriculum developers design mathematics curriculum, they should think carefully about how curricular components can communicate what is to take place in the classroom while simultaneously providing opportunities for teacher learning. In this study, *Eureka Math's* Concept Development lesson component played an important role in the new learning teacher participants acquired as they implemented the curriculum. This component modeled discourse between the teacher and students for each lesson and was followed by a set of problems designed to meet the lesson objective. The design of this lesson component created opportunities for teachers to increase their own understanding of mathematics while also gaining knowledge around how to communicate mathematical concepts to their students. Curriculum developers should seek out ways to design curricular components that embed professional development.

Recommendations for Future Research

Continued study of innovative curriculum materials as a professional development tool and a means to change teacher practice is warranted. To understand how to use curriculum materials as an effective delivery mechanism for teacher development and to effect change in teacher practice, key questions that remain must be answered. This study revealed teachers' independent study of curriculum materials as a prominent method used to acquire new learning. In order to maximize teacher learning through this mode of professional development, it is imperative to determine the types of curricular supports for teachers that are most effective and efficient when it comes to teacher development. The content critical to

convey to teachers through such curricular supports must also be identified. What other curricular design features are essential in achieving impacts on teacher and student learning? The factors leading to successful implementation of new curriculum materials is yet another area to further investigate. And what types and combination of professional development (i.e., formal, informal, independent) around curriculum materials best support teacher learning and the change process? Uncovering the answers to these questions is crucial in the pursuit of using educative curriculum materials at scale to develop teachers of mathematics professionally and to reliably generate enduring changes in their practices which lead to the end goal—increased student achievement.

Additional research around coherence is necessary as this study and others have shown it to be an important factor. Coherence as a characteristic of a professional development program refers to how aligned teachers perceive PD activities to be with: the work they do in the classroom; their goals, knowledge, and beliefs as a teacher of mathematics; and current mandates on curriculum, mathematics standards, and assessment at the school, district, and state level. Coherence also refers to the degree to which activities are consistent across the professional development experience, how integrated the program of teacher learning is. What matters most when it comes to teacher perceptions of coherence? Can we disaggregate coherence, and if so, are certain components of coherence more influential than others? Furthering our understanding of coherence could provide much needed guidance to education leaders at the state, district, and school level.

Closing Thoughts

Prior research has shown that curriculum materials may have a significant impact on teacher development. The present study confirms and complements these findings. This study highlights the specific forms of influence on teacher beliefs, knowledge, and classroom practice and shows the interconnectedness among them. With a retrospective look across multiple years of implementation, the findings give credence to the idea that changes resulting from the process of curriculum use are likely to endure, perhaps due to the self-directed nature of the changes (Spielman & Lloyd, 2005). Scalability has continued to be an issue in the professional development arena. Using innovative curriculum materials holds promise for bringing wholesale change to teachers at an expense that is typically more affordable than many other types of professional development programs.

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APPENDIX A
MODULE DESIGN

Each module has four primary parts: Module Overview, Topic Overviews, Lessons, and Assessments:

- The Module Overview, rich with valuable information, introduces the key components of each module. It outlines the progression of the lessons from the beginning of the module to the end. The components of the overview are as follows:
  - The opening narrative explains the progression of the mathematics through the module topic by topic.
  - Distribution of Instructional Minutes is a diagram that suggests a possible distribution of class time based on the emphasis of particular lesson components in different lessons throughout the module.
  - Focus Grade-Level Standards are the major standards that the module targets.
  - Foundational Standards are prerequisite knowledge that support the Focus Grade-Level Standards. These include standards addressed prior to the module that are essential for student learning and understanding. This section can be helpful in preparing for teaching lessons and for addressing any gaps that might crop up, especially during the first couple of years of implementation.
  - Focus Standards for Mathematical Practice act as a guide to create a well-rounded, standards-aligned classroom environment. This module element highlights which of the eight Standards for Mathematical Practice are a focus of the module and explains how each is addressed in the module.
  - Overview of Module Topics and Lesson Objectives lists each topic in the module, along with the associated standards and lesson objectives. The chart provides the number of days allotted for coverage of each topic. The chart also notes when the Mid-Module and End-of-Module Assessments should be administered during the module and how much time is allotted for each.
  - Terminology consists of both new and recently introduced terms and familiar terms and symbols. Descriptions, examples, and illustrations of the terms are included in this section.
  - Suggested Tools and Representations provides teachers with a list of the models, manipulatives, diagrams, and so forth that are recommended to teach the content of the module.
  - The Assessment Summary gives key information about the assessments of the module, including where within the module they are given and what standards are addressed.
- The Topic Overview lists the Focus Standards associated with the topic. It also provides a narrative similar to that found in the Module Overview but with information regarding specific lessons within the topic. The overview also offers Coherence Links, which reference other modules in the curriculum giving teachers access to foundational and more advanced material related to the topic. A chart detailing the objectives for each lesson is the final feature of the overview.

Figure 5. Description of Eureka Math Module Components (Great Minds, 2015, p. 25)

APPENDIX B
PHASE ONE: SURVEY ADMINISTERED

You are being asked to participate in a research project entitled *"Investigating Curriculum Use and Its Impact on Teachers and Their Practice."* The purpose of this study is to better understand how upper elementary teachers of mathematics use standards based curriculum materials and the resulting changes in their beliefs, knowledge and classroom practice.

This study includes two distinct data collection phases. You are only being asked to participate in the first phase which consists of participation in this online survey. Phase two will occur after analysis of the survey data is complete and consist of interviews with a limited number of teachers and district leaders on a voluntary basis. To participate in this study you must meet the requirements of both the inclusion and exclusion criteria.

This survey is anonymous. No one, including the researchers, will be able to associate your responses with your identity. Your participation is voluntary. You may choose not to participate or to withdraw from the study at any time. By continuing this survey, you are giving consent to participate in this study. The only study risk is the inadvertent release of information contributed, but files will be kept in a secure location to which only the investigators have access.

Questions related to this study can be directed to the following investigators: Tiah Alphonso [redacted]. This study has been approved by the LSU IRB. For questions concerning participant rights, please contact the IRB Chair, Dr. Dennis Landin, 225-578-8692, or irb@lsu.edu.

1. How many years have you been a classroom teacher?

2. How many of your years in the classroom have been spent teaching mathematics?

3. How many years have you been using Eureka Math in your classroom?

4. At what grade level do you currently teach math?

For the next two question sets, you will first be asked to think about your teaching practice NOW and then be asked about your teaching practice PRIOR TO using Eureka Math. Indicate the extent to which you agree with each statement when reflecting on your classroom practice.

5. Think about your teaching practice NOW and indicate the extent to which you agree with each statement below.

	Do not Agree at All	Agree to a Minimal Extent	Agree to a Moderate Extent	Agree to a Good Extent	Agree to a Great Extent
My teaching of mathematics can be described as a balance between procedural skill (fluency), conceptual understanding and real-world application.	○	○	○	○	○

	Do not Agree at All	Agree to a Minimal Extent	Agree to a Moderate Extent	Agree to a Good Extent	Agree to a Great Extent
My teaching of mathematics is aligned to the content outlined in the Common Core State Standards for Mathematics.	○	○	○	○	○
I make a deliberate attempt to identify connections between previously covered content and new content when teaching new topics to my students.	○	○	○	○	○
Using a simple to complex approach, I use manipulatives and/or pictorial representations to introduce new concepts to students before moving to more abstract approaches to problem solving.	○	○	○	○	○
I incorporate fluency activities in my teaching in order for my students to master specific computational skills.	○	○	○	○	○
I incorporate activities in lessons which require meaningful thinking and build understanding of concepts in mathematics.	○	○	○	○	○
I incorporate application problems in lessons which connect math concepts to the real-world.	○	○	○	○	○
I use questioning throughout lessons to check for understanding.	○	○	○	○	○
I teach students strategies for doing mental math (doing math in their head) to build their number sense.	○	○	○	○	○

	Do not Agree at All	Agree to a Minimal Extent	Agree to a Moderate Extent	Agree to a Good Extent	Agree to a Great Extent
I teach students to become proficient in using tape diagrams to solve word problems.	○	○	○	○	○
I use models with my students in order to provide a foundation on which they can build computational strategies.	○	○	○	○	○
I use multiple ways of representing new concepts to my students.	○	○	○	○	○

6. Think about your teaching practice PRIOR TO using Eureka Math curriculum materials and indicate the extent to which you agree with each statement below.

	Do not Agree at All	Agree to a Minimal Extent	Agree to a Moderate Extent	Agree to a Good Extent	Agree to a Great Extent
My teaching of mathematics could have been described as a balance between procedural skill (fluency), conceptual understanding and real-world application.	○	○	○	○	○
My teaching of mathematics was aligned to the content outlined in the Common Core State Standards for Mathematics.	○	○	○	○	○
I made a deliberate attempt to identify connections between previously covered content and new content when teaching new topics to my students.	○	○	○	○	○
Using a simple to complex approach, I used manipulatives and/or pictorial representations to introduce new concepts to students	○	○	○	○	○

	Do not Agree at All	Agree to a Minimal Extent	Agree to a Moderate Extent	Agree to a Good Extent	Agree to a Great Extent
before moving to more abstract approaches to problem solving.					
I incorporated fluency activities in my teaching in order for my students to master specific computational skills.	○	○	○	○	○
I incorporated activities in lessons which required meaningful thinking and built understanding of concepts in mathematics.	○	○	○	○	○
I incorporated application problems in lessons which connected math concepts to the real-world.	○	○	○	○	○
I used questioning throughout lessons to check for understanding.	○	○	○	○	○
I taught students strategies for doing mental math (doing math in their head) to build their number sense.	○	○	○	○	○
I taught students to become proficient in using tape diagrams to solve word problems.	○	○	○	○	○
I used models with my students in order to provide a foundation on which they can build computational strategies.	○	○	○	○	○
I used multiple ways of representing new concepts to my students.	○	○	○	○	○

7. During the time you've used Eureka Math curriculum materials, please indicate the extent to which professional development activities organized by your school or district:

	Not at All	To a Minimal Extent	To a Moderate Extent	To a Good Extent	To a Great Extent
Have been aligned with the school's mathematics curriculum (Eureka Math).	○	○	○	○	○
Have been aligned with the mathematics standards adopted by your school, district and state.	○	○	○	○	○
Have been aligned with state standardized assessments in mathematics your students are administered.	○	○	○	○	○
Have been consistent with your own goals, knowledge, and beliefs as a teacher.	○	○	○	○	○
Have been consistent with the work you do in the classroom.	○	○	○	○	○
Have been consistent across the professional development program, meaning activities are part of an integrated program of teacher learning with activities related to each other.	○	○	○	○	○

8. During the time you've used Eureka Math curriculum materials, please indicate the extent to which you've had the opportunity to engage in the following activities at your school or district:

	Not at All	To a Minimal Extent	To a Moderate Extent	To a Good Extent	To a Great Extent
Collaboratively examine and discuss student work in mathematics.	○	○	○	○	○
Work with colleagues on instructional strategies related to mathematics.	○	○	○	○	○
Meet with other teachers to have meaningful discussions about the mathematics curriculum.	○	○	○	○	○
Meet with other teachers and work math problems from the curriculum.	○	○	○	○	○
Plan daily mathematics instruction with other teachers.	○	○	○	○	○
Discuss implementing ideas from professional development training into your classrooms.	○	○	○	○	○

9. To what extent have you engaged in the following activities with Eureka Math curriculum materials:

	Not at All	To a Minimal Extent	To a Moderate Extent	To a Good Extent	To a Great Extent
Studying Module Overviews at your grade level in an effort to understand how the mathematics progresses through the year.	○	○	○	○	○

	Not at All	To a Minimal Extent	To a Moderate Extent	To a Good Extent	To a Great Extent
Examining the general outline of activities taking place in a lesson for planning purposes.	○	○	○	○	○
Analyzing teaching sequences in a lesson to determine how to make adjustments necessary to meet student needs.	○	○	○	○	○
Studying a segment of problems (e.g., Exit Tickets, Problems Sets, etc.) in the lessons to see the trajectory of the mathematics students are expected to be able to do.	○	○	○	○	○
Studying the lessons to build your own understanding of new ways to teach specific mathematics content.	○	○	○	○	○
Studying Topic Overviews in a module to understand how the content is connected across topics.	○	○	○	○	○
Examining the Teacher/Student sample dialogue in the lessons to formulate questions to be used while teaching the lesson.	○	○	○	○	○
Analyzing the work of your students to determine how an upcoming lesson should be adapted to meet student needs.	○	○	○	○	○
Studying lessons in a topic to understand how the mathematics progresses through the topic.	○	○	○	○	○

10. Since using Eureka Math, what changes have occurred in your beliefs about teaching and/or learning mathematics?

11. What new knowledge or skills have you gained from using Eureka Math curriculum materials?

12. Describe the changes in your practice which occurred as a result of using Eureka Math.

APPENDIX C
IRB APPROVAL

ACTION ON EXEMPTION APPROVAL REQUEST

Institutional Review Board
Dr. Dennis Landin, Chair
130 David Boyd Hall
Baton Rouge, LA 70803
P: 225.578.8692
F: 225.578.5983
irb@lsu.edu | lsu.edu/irb

TO: Tiah Alphonso
Education

FROM: Dennis Landin
Chair, Institutional Review Board

DATE: April 22, 2016

RE: **IRB#** E9912

TITLE: Doctoral Dissertation: INVESTIGATING CURRICULUM USE AND ITS IMPACT ON TEACHERS AND THEIR PRACTICE

New Protocol/Modification/Continuation: New Protocol

Review Date: 4/21/2016

Approved_____X____ **Disapproved**__________

Approval Date: 4/22/2016 **Approval Expiration Date:** 4/21/2019

Exemption Category/Paragraph: 1; 2b

Signed Consent Waived?: Yes for online; No for interviews and administrator consent.

Re-review frequency: (three years unless otherwise stated)

LSU Proposal Number (if applicable):

Protocol Matches Scope of Work in Grant proposal: (if applicable)

By: Dennis Landin, Chairman DLandin

PRINCIPAL INVESTIGATOR: PLEASE READ THE FOLLOWING –
Continuing approval is CONDITIONAL on:

1. Adherence to the approved protocol, familiarity with, and adherence to the ethical standards of the Belmont Report, and LSU's Assurance of Compliance with DHHS regulations for the protection of human subjects*
2. Prior approval of a change in protocol, including revision of the consent documents or an increase in the number of subjects over that approved.
3. Obtaining renewed approval (or submittal of a termination report), prior to the approval expiration date, upon request by the IRB office (irrespective of when the project actually begins); notification of project termination.
4. Retention of documentation of informed consent and study records for at least 3 years after the study ends.
5. Continuing attention to the physical and psychological well-being and informed consent of the individual participants, including notification of new information that might affect consent.
6. A prompt report to the IRB of any adverse event affecting a participant potentially arising from the study.
7. Notification of the IRB of a serious compliance failure.
8. **SPECIAL NOTE: When emailing more than one recipient, make sure you use bcc. Approvals will automatically be closed by the IRB on the expiration date unless the PI requests a continuation.**

**All investigators and support staff have access to copies of the Belmont Report, LSU's Assurance with DHHS, DHHS (45 CFR 46) and FDA regulations governing use of human subjects, and other relevant documents in print in this office or on our World Wide Web site at http://www.lsu.edu/irb*

APPENDIX D

PERMISSION FOR USE OF FIGURE 4

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Title: Examining Key Concepts in Research on Teachers' Use of Mathematics Curricula:

Author: Janine T. Remillard

Publication: REVIEW OF EDUCATIONAL RESEARCH

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VITA

Tiah Alphonso was born in 1973 in Baton Rouge, Louisiana. She received a Master's of Natural Science Degree from Louisiana State University (LSU) in August of 2012. She spent thirteen years in K–12 education as a secondary math and science teacher, an instructional coach, and a high school administrator. Mrs. Alphonso currently serves as Co-Director of LSU's Gordon A. Cain Center and as an instructor in the Department of Mathematics. She anticipates graduating with her doctoral degree in Educational Leadership and Research in December of 2016.