A Meta-Analysis on the Impact of Professional Development Programs for K-12 Mathematics Teachers on Students' Achievement

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ABSTRACT

Over the past decade there has been a growing investment in professional development (PD) programs for K-12 mathematics teachers. Researchers and policy makers often inquire about the effect of professional development programs and whether they are having a positive impact on students' learning, and which type of programs aid in students 'academic improvements. In view of the continued concern about the low achievement of U.S. students in mathematics there is a strong need to better understand the effect of PD on student learning and more specifically, which components of PD are more beneficial and are likely to enhance students' math learning. This study offers evidence in an effort fill the gap in the literature by examining the relationship between professional development and student achievement. A meta-analysis methodology was used to synthesize quantitatively and aggregate the results of the prior studies that have used scientific methods and reported numerical results. The time period for the selection of studies is from 2003 to 2014. Findings in this study confirm earlier literature and offers guidance about three effective components (duration, content, and intervention modality) in professional development programs that have been found to have a positive relationship with students' achievement. The results also highlighted the importance of content focus, sufficient duration and multiple modalities of professional development programs aiding teachers in their ability to become more effective in the classroom leading to increased students' achievement in math.

DEDICATION

First, I want to thank God for leading and guiding me through this process. I would not have made it this far, if He were not forever present in my life. I am so grateful and thankful for His continued love, protection, and guidance. Again, He has made a way out of No way for me. I am thankful for the word of God that keeps me daily. There are three scriptures that I often meditated on that helped me get to the finish line: “I can do all things through Christ which strengthens me (Philippians 3:14). We serve a God who is able to do exceedingly abundantly more than we could ask or think according to the power that worketh in us (Ephesians 3:20). They that wait on the Lord shall renew their strength, they shall mount up with wings as eagles, they shall run and not be weary, they shall walk and not faint (Isaiah 40:31).” Thank you Jesus for your word!

To my wonderful husband (Lance), who has unselfishly loved and supported me for over 33 years. I would not have made it thus far without all of your love and support. You have been a blessing to me since the first day we met. Lance you are my soulmate sent to me from God. I am so grateful and thankful that God saw fit for you and I to become one. Thank you for being an awesome husband, best friend, and great father to our children. I would also like to thank you for continuing to encourage me when I sometimes wanted to give up. I love you with all my heart.

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Chapter 1: Introduction

There has been a major movement to reform the ways in which mathematics is taught with the primary goal of increasing teachers' effectiveness in teaching mathematics. The current focus on improving teacher quality and effectiveness is due to the growing concern over low achievement of U.S. students in mathematics and ensuing efforts to increase students' competencies and achievement in mathematics along with closing the gap between U.S. students and their international peers. During the last two decades, researchers have accumulated a large body of literature on math learning, and one critical factor that has emerged from those studies is the importance of pedagogical and instructional practices of the classroom teachers. Under continuing accountability pressures, policy makers, at all levels, have advocated for more professional development (PD) for teachers so teachers can gain more skills, content knowledge and better math pedagogy to improve all students' math learning.

Despite increasing investment in professional development of teachers, the effect of participation in PD on student achievement is unclear. Early studies on PD generally examined self-reported teacher outcomes (such as increase in content knowledge, greater self-efficacy in teaching and classroom management) rather than linking PD to student outcomes. Furthermore, the results of the studies focused on the effect of PD on student learning have been somewhat inconsistent. For example, studies have used different components of PD such as duration, delivery modality, and focus on instruction versus content knowledge. Because of the continued concern about the low achievement of U.S. students in math, a strong need exists to better understand the effect of PD on student learning and, more specifically, which components of PD are more beneficial and are more likely to enhance students' math learning.

The present study attempts to fill the gap in the literature by examining the relationship of PD to student achievement. The purpose of this study is to examine the effect of professional development of K-12 mathematics teachers on the math achievement of students in previous studies. More specifically, the study will synthesize quantitatively and aggregate the results of the prior studies that have used scientific methods and reported numerical results. The time period for the selection of studies is from 2003 to 2014. The goal is to bring strong empirical evidence to understanding the role of PD in increasing student achievement. A meta-analysis methodology will be used to evaluate effect size showing the impact of professional development components (duration, content, and intervention) on students' achievement. This study will explore whether effect size varies depending on the type of professional development program (content versus pedagogical focus); duration of the program (1 year versus multiple years); and program components (workshop only, workshops and coaching, or workshops and other components) (Scher & O'Reilly, 2009). Professional development (independent variable) is defined as the acquisition of skills and knowledge through formal experiences (attending workshops, professional meetings, coaching, mentoring, etc.) within schools and/or throughout the school district that focus on improving teachers' knowledge of content and pedagogy. Students' achievement (dependent variable) is defined as gains in students' performance in mathematics. The components of achievement will include grades, test scores, and state assessments scores.

Background and Overview

With the establishment of the Institute for Education Sciences (IES) by the United States Department of Education during the George W. Bush administration, an important change in the study of professional development occurred. IES changed the educational research focus from developmental, descriptive, and survey based research to inquiries built around random assignment studies (Hill, 2011). The mission of IES is to provide rigorous and relevant evidence on what works, what doesn't, and why, thus aiming to improve educational outcomes for all students as well as influencing practices and the implementation of policies in the educational community (U.S. Department of Education, 2002).

Importance of Math Learning and Professional Development

The need for Math and Science educational reform has been a subject widely discussed since the 1960's and 70's. According to Burris (2014), a space race between the Soviet Union and the United States was ignited after the Soviets launched the Sputnik (satellite) in 1957. As a result, there was a growing concern that the United States was falling behind in the areas of math and science. This concern sparked the formation of "New Math Reform" in the 60's and 70's; the program emphasized mathematics based on set language and properties, proof, and abstraction. Opponents criticized The New Math curriculum arguing it created more math confusion and failed to meet the challenge of increasing U.S. students' competencies in mathematics. By the 70's and 80's, the new trend of math reform was "Back to Basics", which focused on "arithmetic computation and rote memorization of algorithms and basic arithmetic facts" (Burris, 2014, p. 1). This math curriculum concentrated on basic skills and did not lead to increasing students' mathematics competencies.

In 1989 The National Council of Teachers of Mathematics (NCTM) developed standards to advance teaching and learning in mathematics. These standards aided students in their problem solving, communication, connections, and reasoning skills. By the 1990's, professional development for teachers had become a central part of educational reform to increase student achievement (Elmore, 1996). Many school districts were using some form of professional development with little or no success in increasing students' mathematics achievement. In 1991, The National Council of Teachers of Mathematics developed The Professional Standards for Teaching Mathematics, which focused on the premise that teachers are the main change agents in reforming the way mathematics is taught and learned, and that school districts should provide teachers with long-term support and adequate resources. According to NCTM (1991) these standards will assist with curricula, teaching, and assessment to improve mathematics education.

Since the evolution of the New Math Reform, the educational system has experienced extreme pressure to increase student achievement in mathematics by meeting academic goals that were established by the federal government. The No Child Left Behind (NCLB) Act of 2001, which increased the standards of accountability for states, school districts, and schools, aimed at improving student's achievement in reading and mathematics (NEA, 2010). The Annual Yearly Progress Standards (AYP) administered by the federal government under the NCLB has led many states to employ their own standardized test to measure student achievement with harsh penalties if standards are not met. Furthermore, school districts are attempting to find the perfect strategy (curriculum, tutoring, highly qualified teachers, and after school programs, etc.) to meet the state and federal accountability standards.

Subsequently, with the adoption of the NCLB, there has been a major focus on improving teachers' quality in the educational community along with teaching effectiveness in U.S. schools (Blank & de las Alas, 2009). Teacher quality is considered a key element in improving primary and secondary education in the United States (Harris & Sass, 2011). Since quality is a key element, the main goal of the NCLB Act was to have highly qualified teachers in every classroom effectively teaching, thus closing the achievement gap between U.S. students and their international peers. The law defines highly qualified teachers as "having 1) bachelor's degree; 2) full state certification; and 3) demonstrated competency as defined by the state, in each core academic subject that they teach" (NCLB, 2001, p. 1). Research has shown that obtaining the highly qualified status is achievable. Birman et al. (2009) reported that in 2006-2007 most mathematics school teachers in the United States were considered highly qualified even though highly qualified has different meanings depending on the state. Research has also found that "teachers have a more significant influence on student achievement than any other school factor, and they [teachers] vary widely in their impact" (Archibald, Coggshall, Croft & Goe, 2011, p. 1). According to Aaronson, Barrow, and Sanders (2007), math teachers' quality affects students' achievement. This study indicated that teachers who were one standard deviation above average had a positive impact on students' gains in mathematics compared to average teachers. Since research has discovered a link between effective teaching and achievement, major attention has been placed on teachers' preparation process along with continued in-service training (Scher & O'Reilly, 2009).

Current Issues in PD for Math Teachers

Recent research has provided support for the important role of PD and has highlighted the need for increasing both math content knowledge and math pedagogical knowledge of teachers. For example, in a review of 57 studies conducted by Wilson, Floden, and Ferrini-Mundy (2002) researchers found a positive relationship between teachers' subject matter knowledge and higher student achievement. This study concluded teachers' education coursework (method courses)—which often include research based math education practices and teaching strategies—is directly related to teachers' performance. Whereas, subject matter coursework, such as teachers taking more than four to six math courses, had little effect on student achievement. In math education research, scholars have shown that the amount of mathematical knowledge needed to teach children outweighs the number of math courses one has taken (Ball, Thames & Phelps, 2008). All experts in the mathematics teaching field agree that math content knowledge is important, but the problem lies with teachers that may know the mathematics but cannot teach it to their students. Thus, the current focus of PD seems to be to increase the math pedagogical knowledge.

According to Scher & O'Reilly (2009), experts generally agree that teacher knowledge is critical in promoting student achievement, but less agreement exists on the type of content knowledge or pedagogical knowledge teachers need to be effective in the classroom. Hill (2011) stated that professional learning opportunities are one way to enhance teachers' content knowledge. Evidence suggests a positive correlation between students' mathematics achievement and the mathematical knowledge/training levels of mathematics teachers (Yoon, Duncan, Lee, Scarloss & Shapley, 2007). This correlation was based on teacher's computational abilities as it relates to students achievement in mathematics. Hill, Rowan, and Ball's (2005) study showed that teachers' mathematical knowledge as well as their pedagogical content knowledge (PCK) together has a greater effect on student's mathematics achievement than teachers' content knowledge alone. In view of the on-going debate over the relative merits of different approaches, aspects of PD such as teachers' content knowledge, pedagogical content knowledge, intervention programs, and duration of program need to be evaluated in professional development models to provide evidence of its impact on student gains in mathematics.

For the past 20 years, multiple education reforms exist advocating teachers as the most effective change agent for improving student achievements (Scher & O'Reilly, 2009). Another reason for the importance of effective teaching in math is the specific nature of math learning. Students learn math in classrooms as opposed to other subjects which may be learned in other settings. For example, as shown by earlier research (Bodovski & Farkas, 2007), students' mathematics progress is more dependent on what they learn in school as opposed to language arts in which their linguistic ability is heavily influenced at home by their family's culture. Since students' growth in mathematics is contingent on teachers' effectiveness, professional development opportunities implemented by school systems have a vital and positive impact on teaching practices and lead to gains in student achievement.

Consequently, the National Science Foundation (NSF), The United States Department of Education, and other governmental and non-governmental organizations made substantial investments to improve K-12 students' performance in math and science in an effort to close the achievement gap between U.S students and their international peers by improving teachers' classroom teaching (Hill, 2011). The National Science Foundation spent about 1.2 billion dollars between the years of 2002 and 2007 offering mathematics and science learning experiences to pre-service and in-service teachers in an effort to increase the quality of teaching and learning (Hill, 2011).

With the growing concern of schools meeting the demands of the federal government, state standards, along with efforts to close the achievement gap, many school districts are leaning toward improving student's mathematics achievement by increasing teacher's content and pedagogical knowledge through professional development. Overall, the need for continued and effective professional development for teachers is well established. Given the heavy investment in PD, it is critical to examine the effect of professional development on students' outcomes. The proposed study will attempt to examine the various aspects of the PD programs and their impact on student learning.

Research Questions

This study will use the techniques of meta-analysis in gathering and synthesizing the previous studies and their results. The overall impact of PD on student outcomes is not fully understood and especially what kind of PD is needed to improve student outcomes. Therefore, this study shifts the attention from teacher outcomes of PD to student outcomes and fills an important gap in the literature. To provide support to the new findings on the impact of mathematics teachers' professional development on student achievement, the research questions posed in this study will focus on rigorously designed studies. This research will answer the following questions:

1) What is the average impact of rigorously evaluated and recent professional development programs on math student achievement?
2) Among these rigorously evaluated programs, how do these effects vary? Do programs that incorporate the characteristics that have been asserted through theory and practice to be particularly beneficial to professional development programs have stronger effects than programs that do not?

The Scher and O'Reilly (2009) meta-analysis study spanning from 1990 thru 2003 examined the variables (duration, content, and intervention). This study will focus on new empirical research findings about the impact of mathematics teachers' professional development on students' achievement from 2003-2014.

Objectives of the Study

This study, using the methodology of meta-analysis, aims at examining the effects of professional development on students' outcomes. The primary goal of this study is to examine and understand the effects of professional development on students' gains in math achievement as evidenced by the prior studies conducted in the last decade. Given the current focus on teachers' effectiveness in teaching math and the need for continued professional development, a need exists for aggregation and synthesis of the current studies to understand what components of professional development benefit students. Many studies have examined professional development for math teachers but, due to differences in the methods (teachers' self-reporting), content focus (teachers' perceptions), and small samples, the outcomes are varied. In addition, a large amount of studies have examined the teachers' outcomes only. However, many published papers, theoretical in nature and not based on empirical data, exist on teacher or students' outcomes. This meta-analysis will fill in the gap by bringing studies together from 2003-2014 to evaluate the impact of professional development components (duration, content, and intervention) on students' achievement; and explore whether effect size varies depending on the type of professional development program.

With research showing that teachers are the main agent for change when it comes to student achievement, another goal of this study is to provide useable findings that offer school system leaders and policy-makers scientifically-based evidence on improving students' achievement. The final goal is that the results of this study will help K-12 mathematics educators and school level decision-makers select and develop professional development programs within their schools or school districts based on programs that are found to be scientifically effective.

Rationale

Although experts agree that teachers' knowledge is critical in promoting student achievement, uncertainty exists in the type of content knowledge or pedagogical knowledge teachers need to be effective in the classroom (Scher & O'Reilly, 2009). Another obstacle when investigating the effect of professional development models for evidence of improving student mathematics achievement is finding research that uses good measures for teacher content knowledge and practice (Scher & O'Reilly, 2009). For example, the National Mathematics Advisory Panel Report (2008) reported that the number of courses a teacher has taken or certification credentials received are often used in research to measure teachers' content knowledge. Yet, research has found that math courses taken and certification credentials have showed mixed results regarding their relationship to teachers' content knowledge and students' achievement. This lack of valid and reliable measures of teachers' mathematical knowledge has hindered the promotion of strong empirical evidence linking teacher knowledge and student learning (National Advisory Mathematics Board, 2009). According to Hill et al. (2005), many researchers measure teachers' mathematical knowledge far too often on the number of math courses they have taken. Teachers, however, must be able to understand the mathematics "and use subject-matter knowledge to carry out the tasks of teaching" (p .372). Thus, teachers' formal schooling characteristics and certification credentials are inadequate measures of their knowledge. These findings limit the conclusions that could be drawn in regards to the impact of teachers' knowledge on students' learning (Hill et al., 2005). Hanssen's (2006) study in which he summarized results of an explanatory path analysis and attempted to show a relationship between teachers' characteristics and knowledge, classroom practice, and student achievement outcomes is another example of poor measures. A correlational relationship was found between the variables using a path analysis offering very little predictive power for student achievement outcomes. Indeed, other factors could have influenced student achievement and teacher practices and should have been controlled in the model but were not. Therefore, more studies should be conducted in the area of teacher content knowledge and practice offering strong empirical evidence linking teacher knowledge and student learning (Scher & O'Reilly, 2009).

Numerous controversies exist concerning professional development for teachers. One of the controversies is what constitutes an effective teacher (Telese, 2012). Another controversy is "how to best prepare new teachers and how to improve the quality of the existing teacher labor force" (Harris & Sass, 2011, p. 798). The research is not clear on what characteristics of a professional development model are best that aid in teacher learning, practices, and students' achievement. In addition, professional development for in-service teachers is very expensive and thus, with mounting accountability pressures school systems need to evaluate the returns on their investment (Telese, 2012). Lastly, with the vast amount of professional development research, very few studies measure the linkages among changes in knowledge, teacher practices, and student outcomes (Scher & O'Reilly, 2009). This study will attempt to contribute evidence to clarify some of the issues about effects of PD and offer guidance about the PD components that seem to be effective. By summarizing and comparing effect sizes based on meta-analysis of research findings in the areas of K-12 mathematics teachers' professional development and students' achievement from 2003 – 2014, this study will have a substantive impact in identifying the effective professional development components (duration, content, and intervention).

Summary

This chapter presents the purpose of the study, the background and overview of the importance of math learning and professional development, the current issues regarding components of an effective professional development model, and the research questions that guide the study. To summarize, this study will use meta-analysis to provide a quantitative synthesis of studies from 2003-2014. The goal of this study is to examine the effect of professional development for math teachers on student achievement. Professional development is considered a key factor in improving teachers' content and pedagogical knowledge and in increasing students' mathematics achievement. Thus, it is important to examine the current literature on professional development and synthesize the various elements (duration, content, and intervention) of professional development in evaluating the success of these models.

Chapter 2: Literature Review

The purpose of this study is to examine the relationship of professional development of K-12 mathematics teachers and achievement of students. With professional development being the critical mechanism for improving teaching practices and promoting students gains in mathematics (Tournaki, Lyublinskaya, & Carolan, 2011), the goal of the literature review is to create a conceptual framework for the study.

The threat of the United States failure to educate its students to the level of competing in a global economy is a serious concern of the United States government. The Council of Foreign Relations in 2012, which was co-chaired by the former United States Secretary of State Condoleezza Rice stated that "the country will not be able to keep pace-much less lead-globally unless it moves to fix the problems it has allowed to fester for so long" (Hanushek, Peterson, & Woessmann, 2012, p. 1). This notion supports President Barack Obama's 2011 State of the Union Address declaring, "We need to out-innovate, out-educate and out-build the rest of the world" (Hanushek et al., 2012, p. 1). Research has found that "teachers have a more significant influence on student achievement than any other school factor" (Archibald et al., 2011, p. 1). They are considered the main agent for change. Therefore, teachers' learning is essential in improving students' learning and leads to gains in achievements (Killion, 2002). To aid the research community in offering evidence on decreasing the achievement gap between the United States students' and their international peers, this literature review will focus on six distinct topics: a) the importance of professional development for K-12 mathematics teachers; b) the characteristics of effective professional development models; c) the need for rigorously designed professional development models; d) alternative forms of rigorously designed professional development models; and e) the justification for using the meta-analysis methodology to evaluate effect size showing the impact of professional development components (duration, content, and intervention) on students' achievement.

The Importance and History of Professional Development for K-12 Mathematics Teachers

Professional development for K-12 Math Teachers

In the educational research community the term staff development, in-service, and professional development are often used interchangeably (Cooper, 2004). There have been numerous definitions for the term "professional development." One current and common theme for professional development in math education is to offer activities that are designed to increase skills and knowledge of educators to aid in improving teaching, student learning, and achievement. For the purpose of this study, professional development is defined as the acquisition of skills and knowledge through formal experiences (attending workshops, professional meetings, coaching, mentoring, etc.) within schools and/or throughout the school district that focus on improving teachers' knowledge of content and pedagogy.

Professional development has been considered one of the most important elements used to increase teachers' knowledge and skills. Thomas Guskey (2004) stated that "one constant finding in the research literature is that notable improvement in education almost never takes place in the absence of professional development" (p. 4). With the global educational reform movement setting high goals and standards for students learning all around the world (Borko, 2004), there is an urgent need for effective professional development. A strong consensus in the research literature suggests the key to improving the quality of U.S. schools is through teachers' professional development (Desimone, 2011).

History of Professional Development in Mathematics

The early years of professional development during the 1960's were focused on "generic" teaching skills such as "allocating class time, providing clear classroom demonstrations, assessing students comprehension during lectures, maintaining attention, and grouping students" (AERA, 2005, p. 1). These forms of professional development offered small to moderate positive effects on students' basic skills (AERA, 2005). Since the 1960's and 70's, the need for Math and Science educational reform has been a subject widely discussed.

In the 1990s and early 2000s, professional development in education was not aligned with the reform movement in math education. The approach to professional development needed to be more purposeful and strategic in an effort to improve teaching and learning (Church, Bland, & Church, 2010). Some of the ineffective practices of professional development were one-time workshops, university courses, and professional development delivered by outsiders while teachers listened in a passive manner (Danielson, 2006; Sparks & Hirsh, 1997). Sparks and Hirsh (1997) identified the need to change the way professional development was being conducted. He stated that it should no longer be fragmented and last minute, but instead the approach to professional development should be conducted with a clear and coherent plan guided by the school districts' strategic plan. Current research has shown that professional development is critical for teachers' learning (Desimone, Smith, & Ueno, 2006). In addition, professional development is central in improving students' learning and achievement (Loucks-Horsley & Matsumoto, 1999). According to Loucks-Horsley and Matsumoto (1999, p. 1), the National Commission on Teaching and America's future (NCTAF), 1996 reported some troubling statistics:

1) Annually, over 50, 000 untrained people enter teaching on either emergency or substandard licenses.

2) Nearly one-fourth (23%) of all secondary teachers do not have a college minor in their main teaching field. More than 30% of mathematics teachers fall into this category.
3) More than (56%) of high school students taking physical sciences courses, 21% English, and 27% in mathematics courses, are taught by teachers who do not have background in these fields.
4) In high poverty schools and in lower classes, the proportion of teachers inadequately prepared is even higher (pp.15-16).

These findings showed that there was a serious need for an increase in teacher quality that would promote students' learning. Teachers' quality was addressed in the No Child Left Behind Act (2001), requiring teachers to have a) bachelors' degree; b) full state certification; and c) demonstrated competency as defined by the state, in each core academic subject that they teach to be considered highly qualified. With research indicating that teachers are the major change agent within schools in regards to students' gains, professional development has been the central focus for student achievement since the 90's (NCTM, 1991; Elmore, 1996).

Throughout the history of math reforms, professional development for mathematics teachers has taken on many different forms with a range of quality and effectiveness (Tournaki et al. 2011). Research continues to show that one-stop professional development (e.g. workshop) is not effective for teachers' learning, even though they are still offered within some schools (Garet, Porter, Desimone, Birman, & Yoon, 2001; Cooper, 2004). Educational systems must provide effective professional development contrary to what has been offered in the past (Darling-Hammond & Richardson, 2009). To address the issue of ineffective professional development, the No Child Left Behind Act was established creating standards for effective professional development.

The Characteristics of an Effective Professional Development

Effective Professional Development

In 2001, The No Child Left Behind Act (NCLB) required that states offer high quality professional development to all public school teachers (Borko, 2004). There were five categories provided for an effective professional development, but Yoon et al. (2007, p.4) streamlined them into three categories:

1) It should be focused, coherent, well defined, and strongly implemented.
2) It should be based on a carefully constructed and empirically validated theory of teacher learning and change.
3) It should promote and extend effective curricula and instructional models-or materials based on a well-defined and valid theory of action.

Yoon et al. (2007, p. 4) stated that:

> Professional development affects 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. If one link is weak or missing, better student learning cannot be expected. If a teacher fails to apply new ideas from professional development to classroom instruction, for example, students will not benefit from the teacher's professional development.

No professional development will ever be effective unless teachers buy into the process. When teachers put the knowledge and skills they have learned from professional development into practice within their classroom, leading to improved instruction and followed by students' gains, then it is considered effective (Mizel, 2010).

High quality professional development activities are defined as activities that (Joyce & Showers, 2002, p.1): a) improve and increase teachers' knowledge of the academic subjects the teachers teach, and enable teachers to become highly qualified; b) are highly quality, sustained, intensive, and classroom-focused in order to have positive and lasting impact on classroom instruction and the teachers' performance in the classroom; and c) are not one-day or short-term workshops or conferences.

Since the adoption of NCLB, professional development has been identified as the critical mechanism that can assist teachers with increasing students' gains (Tournaki et al., 2011). Hence, teacher quality is essential for students' learning. The role of the teacher is extremely important in the success of students (Cooper, 2004). Furthermore, success for students is dependent on teachers' knowledge and skills and teachers' knowledge and skills are dependent on their training. Consequently, with the new reform, teachers' knowledge and skills are no longer their responsibility alone. It is the responsibility of both teachers and the educational system (Cooper, 2004). According to researchers, "Sustained and continuous professional development growth toward effective…instruction is every educators' and every schools' responsibility" (Learning First Alliance, 2000, pg. 2). The road to closing the achievement gap starts by producing high quality teachers through effective professional development. Thus, professional development for teachers is one of the major factors in improving the quality of United States' schools (Desimone, 2011). When it comes to professional development, the National Council of Teachers of Mathematics indicated that increasing students' learning by means of improved instruction should be the primary goal of professional development" (Doerr, Goldsmith, & Lewis, 2010).

According to NCTM (2010), for the past three decades research has shown that there are four core goals of mathematics professional development when promoting growth in teachers that will promote student learning through better instruction:

1. Build teachers' mathematical knowledge and their capacity to use it in practice.
2. Build teachers' capacity to notice, analyze, and respond to students' thinking.
3. Build teachers' productivity habits of mind.
4. Build collegial relationships and structures that support continued learning (Doerr, et al. 2010, p.1).

As we examine the first core goal, research has shown that teachers' knowledge has a significant impact on students learning and gains (Hill & Ball, 2005; Jacobs, Borko, Koellner, Schneider, Eiteljorg, & Roberts, 2007). Hill et al. (2005) stated that mathematical knowledge for teaching infers that teachers are equipped with the appropriate mathematical knowledge necessary to effectively instruct their students. In order for teachers' to be able to enact the mathematical instructions promoting students' learning, they must have a deep understanding of the mathematics (content knowledge) beyond the concepts and procedures (Kilpatrick, Swafford, & Findell, 2001). A number of studies provide evidence to support the second core, that professional development can increase teachers' awareness not only to value but also analyze their students' mathematical thinking (Doerr et al., 2010). This increase can occur when teachers are given the opportunity in professional development to attend to students' thinking allowing them (teachers) to shift their focus from what is correct and incorrect to evaluating students' thinking (Doerr et al., 2010). Research evidence for the third core showed that professional development can assist teachers in developing their beliefs, practices, and attitudes that are necessary for continuous improvement in classroom instruction (Doerr, et al., 2010). The

NCTM (2010) report stated that teachers' beliefs about students' learning, schools' curriculum, and their professional development has an impact on what they learn in professional development. Likewise, other evidence in this report stated that teachers' attitudes and teaching practices are influenced by professional development opportunities. This includes habits of inquiry, curiosity, self-reflection, and attentiveness to students' thinking and experimentation (Doerr, et al. 2010). In addition, research evidence for the fourth core showed that professional development should be embedded in teachers' work environment such as incorporating a professional learning community within schools and fostering opportunities for teachers to build relationships among colleagues that support teachers' ongoing learning (Doerr et al., 2010). Research has shown that for the four core goals to be successful in improving students' learning through better instruction, the professional development model should include substantial time investment, systematic support, and opportunities for active learning (Doerr et al. 2010).

Empirical Evidence on Professional Development Components

In the last several years, empirical evidence illustrates the most effective professional development programs that aim to increase teachers' knowledge and skills and improve their teaching practice, have the following characteristics:

> a) activities that are ongoing and sustained over time; b) focus on subject matter content and how students learn that content; and c) provide teachers with opportunities to actively interact and engage with each other around curriculum and instruction (Tournaki et al. 2011, p. 300).

Research has also found that professional development that contains these three characteristics is positively related to student achievement (Cohen & Hill, 2001). According to Desimone (2011) empirical analyses have shown five effective professional development components such as content focus, active learning, coherence, duration, and collective participation that have been found to "change knowledge, practice, and to a lesser extent student achievement" (p. 69).

Recently Blank (2013) stated that the meta-analysis conducted by the Council of Chief State School Officers in 2007 goal was to identify research that showed clear evidence of common elements that works to improve teachers' learning promoting student gains. In this research, 16 studies were found to have a significant and positive effect on teachers' knowledge and skills and on students' gains. Five common elements in these professional development opportunities allowed teachers' learning to be transferred into students' learning. The shared professional development components were content focus, longer duration, multiple activities, hands-on teacher learning, specific learning goals, and collective teacher preparation (Blank, 2013).

Components of Teacher Learning

Fewer studies on teacher learning exist because examining teachers' learning is a new concept in research. However, the previous research has shown a link between the professional development of teachers, improved instruction practices and student learning (Borko, 2004). With the current variation of learning needs of students in the 21st century, it is important for teachers to have a deeper content knowledge, more content-specific instructional strategies, and pedagogical content knowledge (understanding how students learn) that will enable them to craft instruction to meet the needs of the students aiding meeting rigorous content standards (Killion, 2002). Research shows that the main target of educational reform is teachers' education (Kleickmann, Richter, Kunter, Elsner, Besser, Krauss, & Baumert, 2013). Many education reforms have relied on teachers' learning as an avenue to improve instruction with the goal of increasing students' learning (Desimone, 2011). Experts have agreed that teachers' knowledge is critical in promoting students achievement (Scher & O'Reilly, 2009). The two important components in teacher learning that have emerged from research are content knowledge and pedagogical knowledge. Content (mathematical) knowledge and pedagogical content knowledge are the types of knowledge that will promote higher math achievement for all students (Hill et al., 2005).

Teachers cannot help students with their understanding if they do not understand the mathematics themselves. Subject matter (content) knowledge (CK) is key to learning how to teach the subject matter (Loucks-Horsley & Matsumoto, 1999). Thus, teachers' understanding of the subject matter (Kleickmann et al., 2013) is the foundation of good teaching. It is imperative that teachers know the answer to a mathematical problem, but they should also know why it is so (Shulman, 1986). The next important type of teachers' knowledge is pedagogical content knowledge (PCK). According to Shulman (1986) (PCK) emphasizes understanding learning in general. Loucks-Horsley and Matsumoto (1999) stated that in a review of in-service programs conducted by Kennedy (1998), she identified three aspects of pedagogical content knowledge that are needed to improve student learning. These aspects are teachers must learn the content of the subject matter, learn how to distinguish whether students are learning or not, and learn ways to teach the specific subject (Loucks-Horsley & Matsumoto, 1999). For subject matter to be accessible to all students pedagogical content knowledge is necessary (Shulman, 1986).

Pedagogical content knowledge is the specialized knowledge that teachers need to be able to teach content to students successfully (Desimone, 2011). This specialized knowledge entails teachers having a deep and meaningful understanding of content, and knowledge of how students' learn which includes the ability to address misunderstandings (Desimone, 2011).

David Cohen (1990) used an illustration to show the dangers of professional development that do not offer teachers the opportunity to foster a deep understanding of mathematical content and how students' learn. In the illustration provided by Cohen (1990), a teacher used manipulatives in a mathematics lesson to aid students' understanding. The teacher had attended an inquiry-orientated math reform professional development that was focused solely on pedagogical strategies (lessons plans or activities). It was assumed that by allowing the students to touch the manipulative their understanding of the content would be increased. The teacher did not have any fundamental understanding of how to use the manipulatives to aid in students' thinking and how to capitalize on the use of the manipulatives when teaching. This example has been used for two decades to show the importance of pedagogical and content knowledge both being essential elements of mathematics teachers' professional development opportunities thus promoting quality teaching leading to student gains (Desimone, 2011). Research has shown that that there is a relationship between teachers' knowledge of content, how students learn content and effective teaching (Grossman, 1990; Leinhart & Smith, 1985). In 2001, Michael Garet and his colleagues conducted the first quantitative study concluding that professional development for math and science teachers should be focused on subject matter content and how students learn the content (Desimone, 2011).

For the last decade, there has been some convincing educational literature that has found professional development to be essential in promoting teacher quality and increasing student achievement. One of the important benefits of an effective professional development is that it can enhance teachers' learning and pedagogical practice promoting students' learning (Kang, Cha, & Ha, 2013). It has been stated that "what teachers know and do impact what their students know and do" (Killion, 2002, p. 11). The value of teachers' knowledge linked to students' learning cannot be underestimated. Studies have found that experienced teachers who have strong content knowledge and effective instructional strategies tend to produce higher achievement among their students (Mundry, 2005). The main mission of K-12 educational system is to prepare students to become contributing productive citizens (Killion, 2002).   One essential factor leading to this goal is to offer effective professional development to all teachers.

Measures of Student Learning

In an effort to raise standards and make education more equitable, President Lyndon Johnson enacted the Elementary and Secondary Education Act (ESEA) in 1965. This act was the beginning of the modern testing movement. The National Commission on Excellence in Education established in 1983 by President Regan, released a report titled "the Nation at Risk: The Imperative for Educational Reform." This report suggested the United States' educational system was in a crisis and that there was an urgent need to raise academic standards. According to the report, the American educational system had "lost sight of the basic purpose of schooling, and of the high expectations and disciplined effort needed to attain them" (NCEE, 1983, p. 1). This sparked the reform advocates to press for stricter accountability measures and increase testing in public schools (Sacks, 2000).

Since the New Math Reform, there has been extreme pressure on the educational system to increase student achievement in mathematics. According to The No Child Left Behind Act of 2001:

> *The legislation funds a number of federal programs aiming at improving the performance of U.S. schools by increasing the standards of accountability for states, schools districts, and schools, as well as providing parents more flexibility in choosing which schools their*

children will attend. Additionally, it promotes an increased focus on reading and math

(NEA 2010).

Each year schools receive a grade from the federal government if they meet the Annual Yearly Progress (AYP) standards. This act has led many states to employ their own standardized test to measure student achievement with harsh penalties if standards are not met. According to Killion (2002), an urgent need for educational reform after the publication of "A Nation at Risk" in 1983 has produced slow or minimal progress in student achievement. The National Assessment of Educational Progress Longitudinal Study (U.S. Department of Education, National Center for Educational Statistics, 2001) confirmed that improving students' academic achievement has been a challenge for educators. Killion (2002) reported that each decade brings new challenges for educators. He stated that the main challenges for educators are the increasing rise of students with diverse learning needs, the high expectations, and increasing demands for raising students' achievement levels by stakeholders.

As What Matters Most: Teaching for America's Future (National Commission on Teaching for America's Future, 1996) stated,

> graduation rates and student achievement in most subjects have remained flat or have increased only slightly. Only a small fraction of high school students can write or compute, and manage scientific material at the high levels required for today's knowledge-based jobs. According to the National assessments, only 10% of U.S. 17 years old can draw conclusions using detailed scientific knowledge; only 7% can solve math problems with more than one step; only 7% can read and understand specialized materials; and a mere 2% can write well-developed materials. Meanwhile, international

> tests continue to show U.S. high schools students ranking near the bottom in mathematics and science (National Commission on Teaching for America's Future, 1996, p.5).

The result of the National Assessment of Educational Progress Longitudinal Study (NCES, 1999) confirmed that raising students' achievement levels is a substantial challenge for educators. The NAEP 1999 Trends in Academic Progress, which has been monitoring the academic progress of students since the 1970s, is the first study to document our nation's progress in education (Killion, 2002). When looking at students' overall academics from the longitudinal study over the last three decades, only small gains appeared in 12th grade performance, regardless of the vast investments that had been made to increase achievement for all students (Killion, 2002). There was an increase in the average mathematics scores in the 1980s and 1990s. The average mathematics scores in 1973 were lower than the 1999 average scores. This difference was found to be statistically significant (Killion, 2002). From these results, it appears that the new reform is having a positive effect on student achievement in mathematics. The significant results in mathematics is encouraging, offering hope that the continued increase in teacher quality will aid in closing the achievement gap between the United States' students and their peers.

Currently, the NAEP 2012 Trends in Academic Progress (NCES, 2013) documented the results of four decades of students, ages 9, 13, and 17 years old and their academic performance in reading (1971-2012) and Mathematics (1973-2012). The results showed that 9 and 13-year-old students in the early '70s scored lower in reading and mathematics than students of the same age in 2012. The 2012 scores were 8 to 25 points higher than the first year assessment of 1973. Unfortunately, seventeen-year olds' average reading and mathematics scores did not demonstrate similar gains. In addition, the average scores were not significantly different than the first year assessment scores of 1973 (NCES, 2013). The summary report also mentioned that 13-year-olds were the only students that made gains in their academic performance in math and reading since the last assessments in 2008 (NCES, 2013).

Effective Professional Development to Closing the Achievement Gap

The main goals of both the national and state education policy is to close the achievement gap (NCES, 2012). The NAEP 2012 Trends in Academic Progress has shown some positive gains in narrowing the gap in the areas of ethnicity and gender. In the realm of state education, it has been a narrowing of racial achievement gaps between White-Black and White-Hispanics scores in reading and math since the 70's. There have been larger gains by Black and Hispanic students than White students. There was not a significant gain in the White-Hispanic gap in mathematics at age 9. Thus, the gap from 1971 to 2012, with respect to gender, showed that female students scored higher in reading than male students regardless of age. The overall results showed that 9-year-old males made larger gains than females. The results in mathematics showed that although 17-year-old female students scored lower than male students, they narrowed the gender gap from 1973 to 2012 (NCES, 2013).

Even though there has been progress in narrowing the achievement gap in the areas of reading and mathematics, the mandate of the No Child Left Behind Act (2001) educational reform calls for closing the gap not just narrowing it. The process of narrowing the gap should be through increasing teachers' quality. Since research has found that teacher quality is the key to increasing student achievement, then the avenue to developing quality teachers is through professional development. Therefore, school districts must ensure effective professional development opportunities for all teachers.

Not all professional development is considered quality. According to Sparks (2002), most professional development has not improved students' learning. He suggests a successful professional development model should focus on the content that teachers teach and methods used to teach the content; it should also be sustained and connect to their daily classroom teaching practices leading to students' learning. Research has stated that high quality professional development should focus on deepening teachers' content knowledge and pedagogical skills. It should also provide opportunities for practice, research, and reflections; job embedded offering opportunities for collaboration during the workday among colleagues; and staying abreast of teaching practices and students' learning (Sparks, 2002).

The Need for Rigorously Designed Professional Development

Empirical Evidence and Professional Development

Even though there has been a large amount of research describing best practices in professional development, there is relatively little research on the effects of alternative forms of professional development and students' achievement (Garet et al., 2001). There are many suggested models of professional development but to enhance students' achievement in mathematics, teachers must learn more about the subjects they teach, have a deeper understanding of the mathematics, and understand how students' learn to carry out the demand of education reform (Garet et al., 2001). The educational reform incorporates high standards, curriculum frameworks, and new approaches to assessment aligned to the standards, which created new expectation for teachers' classroom behaviors and students' performance (Garet et al., 2001).

When focusing on high quality professional development, James Hiebert (1999), in a review of research on mathematics teaching and learning conducted for the National Teachers of

Mathematics in regards to high standards, content focus, and in-depth learning opportunities for teachers stated that

> Research on teacher learning shows that fruitful opportunities to learn new teaching methods share several core features; (a) on going (measures in years) collaboration of teachers for purposes of planning with (b) the explicit goal of improving students achievement of clear learning goals, (c) anchored by attention to students thinking, the curriculum, and pedagogy, with (d) access to alternative ideas and methods and opportunities to observe these in action and to reflect on the reasons for their effectiveness…(1999, p. 15)

Even though these characteristics are often used in literature that represent an effective professional development model, there is little direct evidence on the extent that these characteristics are related to positive outcomes for teachers and students mathematics achievement. Despite the fact that the vast amount of research describing the best practices in professional development for math teachers, there is limited evidence that supports the effectiveness of professional development for increasing teacher skills and students' learning (Church et al., 2010). Consequently, the broad ranges of experiences that teachers encounter as professional development make measuring its effect a challenge (Desimone, 2011). There is an agreed stance among scholars that we need more empirically valid methods of studying professional development (Wayne, Yoon, Zhu, Cronen, & Garet, 2008).

Current Debate on Effective Professional Development Components

According to Guskey and Yoon (2009), in 2007 the scholars from the American Institute for Research analyzed 1343 studies that potentially addressed the effect of professional development on students' learning. The findings were published in the report titled "Reviewing the Evidence on How Teacher Professional Affects Student Achievement" (Yoon. et al., 2007). To the surprise of many scholars, out of 1343 studies only 9 studies met the rigorous requirement standards set by the What Works Clearinghouse (WWC). The U.S. Department of Education's Institute of Education Sciences (IES) under the Education Science Reform Act (2002) established the WWC. The primary mission of the WWC is "to be a central and trusted source of scientific evidence for what works in education" (IES, 2010, p.1). What Works Clearinghouse only reports the results of studies that they have high to moderate confidence in the research. Their confidence is built on the premise that the impact of the intervention in the study was the sole factor of the evidence found in the study, and that the impact was not attributed to any other factors within the school and student lives (IES, 2010). The nine studies were conducted between 1986 and 2003 with the sampled population being elementary students, no middle or high school student were included. The findings from the Yoon et al. (2007) study showed that the relationship between professional development and student achievement is complicated (Guskey et al., 2009). Another surprising finding was that some of the frequent characteristics that were considered contributing factors to the effectiveness of professional development endeavors were not factors in these studies, and some shared characteristics were different from the noted frequent factors in previous professional development research (Guskey et al., 2009). The nine studies in the Yoon et al. (2007) study found the following characteristics to have a positive relationship between professional development and improvement in student learning (Guskey et al., 2009):

1) Sustained supported workshops or summer institutes (research-based instruction, involved interactive learning, offer teachers opportunities to adapt practice to unique classroom situations).

2) Focused on ideas gained through the involvement of the outside expert, program author, or facilitators helping teachers to implement program.
3) Requires considerable amount of time, it must be well organized, carefully structured, purposefully directed, and focused on content or pedagogy or both.
4) Significant amount of structure and sustained follow up after initial professional development.
5) No common activities were identified in this study that were linked to student improvement.

In summary of the nine studies, it was found that teachers who received on average 49 hours of professional development increased their students' achievement by 21 percentile points. In addition, studies that offered more than 14 hours of professional development showed a positive and significant effect on student achievement. On the other hand, there was no significant effect found on student achievement from the three studies that offered teachers 5-14 hours of professional development. All nine studies employed workshops or summer institutes that went directly to teachers and varied in duration and intensity (Yoon, et al., 2007). There were follow-up sessions to support the professional development for eight of the studies.

In support of the current findings, the National Staff Development Council (2001), argued that "the most effective professional development comes not from the implementation of a particular set of "best practices," but from the careful adaptation of varied practices to specific content, process, and context elements" (Guskey et al. 2009, p. 497).

Present Problems with Professional Development with Emergence of Empirical Findings

Even with the vast amount of research studies on professional development (PD), the appropriate methods of researching PD are often a topic for educational researchers. According to Hill, Beisiegel and Jacob (2013) randomized trials have not enhanced the research community about the effectiveness of professional development programs characteristics; moreover, there should be some guidance on the best practices when researching professional development. It has been a consensus from studies over the past twenty years on certain elements of professional development models that have often been reported to maximize teachers' learning. According to Hill et al., (2013), these elements are a) strong content focus, b) inquiry-orientated learning approaches, c) collaborative participation, and d) coherence with school curricula and policies.

Lately there has been rigorous professional development research with randomized trials and the results are not in agreement with these four elements maximizing teachers' learning. The reason for this disagreement is not known, but it does bring about some concerns in regards to how it contradicts conventional wisdom among researchers. Hill et al., (2013) suggested that some of the reasons could be

> The content of the specified programs evaluated may have been ineffectual, or programs may have deviated from best practices in important ways due to poor implementation or difficulties scaling the program to multiple sites. Poor research design-inadequate measures, insufficient power-may also contribute to these findings (Hill et al., 2013, p. 476).

This brings the issue to the forefront of re-evaluating the research paradigm in professional development. According to Hill et al., (2013) many professional development programs are "home-grown" meaning that it is developed due to the needs of school districts or local developer needs and interests. This often leads to little or no formal evaluation of whether the program promotes teacher learning and positive student outcomes.

Hill et al. (2013) offered 4 rigorous comparisons of new approaches to research on professional development programs at the initial states of the program. The four suggested comparisons are:

1. Design should link to open questions with PD literature allowing the community to accumulate evidence on issues of importance to local providers.
2. Initial work should have multiple groups of teachers and multiple facilitators, more than one location.
3. Analysts should conduct meta-analyses that inform these open questions as studies accumulate.
4. Analysts should provide background on the history of the PD research and describe the trends toward large-scale experimentation that have occurred in recent years (p.476).

The effectiveness of professional development programs have been evaluated using different measures during the last couple of decades. In the 1990s, it was based on teachers' reports of change or satisfaction; later some scholars compared the effect of the program features rather than the program and others focused on research designs that featured random assignments of teachers, schools or treatment conditions allowing for causal effect to be made (Hill et al., 2013).

In 2004, Hilda Borko developed a three phase approach to studying professional development. In that approach, she noted the following characteristics:

1. Analysts of professional development at single site-teachers as learners, and the relationship between these 2 elements.
2. Analysts of a single professional development program enacted by more than one facilitator at more than one site, exploring the relationships among facilitators, the PD program, and teachers as learners.
3. Analysts of comparing multiple professional development programs, each enacted at multiple sites-studies the relationship between all 4 elements: facilitator, PD program, teachers as learners, and context (Borko, 2004, p.4).

Another important method of studying professional development occurred during the George W. Bush administration, when the Institute for Education Sciences (IES) was established by the U.S. Department of education. IES changed the educational research focus from developmental, descriptive, and survey based research toward inquiries built around random assignment studies (U.S. Department of Education, 2002; Hill et al., 2013). IES (2012) developed four goals to support random assignment research and offered competitive grants aiding in research opportunities. Those four goals are as follows:

1. Exploratory-generating hypotheses or theories from existing datasets;
2. Development and innovations-development and innovation-positive effect on study outcomes, often in a single pilot study setting.
3. Efficacy and replication. Implementing successful Goal 2 interventions in authentic yet favorable settings to determine their effects on student outcomes, usually across multiple sites;
4. Effectiveness. Determining whether successful Goal 3 interventions continue their success under conditions of routine practice and at multiple sites

(Hill et al., 2013, p.476).

With the introduction of random assignment research studies on professional development, there has been contradicting results in contrast to elements that have been found to enhance teachers' professional development outcomes. These elements that are in question are generous time in professional development, content focus, active learning opportunities, collaboration among teachers, and collective participation within schools (Garet et al., 2001). According to Hill et al. (2013) some of the reasons why these random assignment studies may not have found these elements to have any impact on teachers' professional development experiences could be due to "ineffective content, poor or incomplete programs implementation, inadequate statistical power, poor measures (e.g. lack of alignment between intervention and outcome measures), problematic randomization, or improper data analysis" (p. 478), and in some cases it could be poorly designed programs.

Suggested Design Elements for Effective Professional Development

Researchers have suggested some desirable research designs for the study of professional development programs. Hill et al. (2013) suggested that the method of conducting research on professional development needs to be re-evaluated and has proposed the following five-stage professional development research design:

1. One site pilot (4- 6 sessions)-to ensure the feasibility of the program-changes in the features could be assessed in successive sessions-with feedback from teachers and developer.
2. Randomized clinical trial-holds the content constant-developer may want to work in a school or district with idea conditions-supportive administration, common planning time, alignment of curriculum, and assessment with PD. Provision PD with each feature to

multiple groups of individuals by multiple facilitators. Use low cost outcomes to gauge the initial success of the program.

3. Developers would modify and finalize the intervention materials or protocols and then take them into a traditional efficacy trial.
4. If successful-program would enter Stage 4-where scale-up trials would track the effects of the program as disseminated under standard (market) conditions. Goal 3 and 4 could take up to 2 to 3 years costing between 1 to 3 million.
5. Collecting evidence from stage 2, 3, 4 trials and conducting either meta-analyses or structured reviews of these findings. Scholars could also investigate the effect of contextual factors on PD effectiveness (pp.480-482).

There are several advantages to this approach. First, the researcher would be able to rigorously test various adaptations during the development phase. This approach promises to augment the impact on classroom instruction and student learning. Second, it prevents the evaluation of the program from being site specific. Finally this would not only simplify analysis but would also make the program cost efficient by including traditional control groups (Hill et al., 2013)

According to Hill et al., (2013), it is important for the professional development research community to develop guidelines with regards to best practices for conducting research on the paradigm of professional development research. With more rigorous comparisons of PD designs at the initial stages of the program development, the gained information from these studies could be used to build a professional development knowledge base. A prime example for this change is the Yoon et al. (2007) study of 1343 studies with only nine studies qualifying as being effective professional development models. Providing guidelines for best practices for conducting professional development research could aide in generating more usable knowledge for the field and improves the likelihood of effective teachers' instruction and positive students' outcomes.

Alternative Forms of Professional Development since NCLB (2001)

Professional Development Models and Student Outcomes

After the adoption of NCLB (2001), which is often referred to as the accountability era, there has been an increase in empirical professional development research. In the past, research on professional development and its link to student outcomes have been based on how teachers feel about their teaching practices (efficacy) through surveys. In addition, there was another phase of research evaluating teacher characteristics (level of education attained, number math classes taken, teaching experience etc.) in relation to students' outcomes. Later there was a wave of studies that surfaced examining teachers' outcomes through learning. This birthed the link between teachers' content knowledge and pedagogical content knowledge as it relates to gains in students' achievement. Currently, professional development research has evolved into evaluating professional development programs and its effectiveness in increasing teachers' knowledge content knowledge (CK) or pedagogical knowledge (PCK) or both as it is related to increasing students' achievement. With this new phase of research evaluating the effect of professional development on student achievement, alternative forms of professional development programs will be examined offering evidence of their effect on teachers' content knowledge and/or pedagogical knowledge and student achievement. The following findings were concluded when examining five alternative forms of professional development models: content focused, curriculum focused, problem solving focused, and on-line focused, and Formative Assessment in Middle Model (FAMM) professional development models for mathematics teachers.

Teachers' Content Focused Professional Development

Desimone et al. (2006) conducted a content focused professional development research study. Their article, "Are Teachers Who Need Sustained Content Focused Professional Development Getting It?," explored "whether professional development primarily performs an educative function by addressing weak teacher preparation or a catalytic function by serving mainly teachers who already have a strong background in their field" (p.179). It was hypothesized that content knowledge might distinguish teachers who take high content-focused professional development from those who take medium content-focused professional development, but might not necessarily distinguish between teachers who take low and medium content-focused professional development.

For the past twenty years, mathematics research has shown that both pre-service and in-service mathematics teachers on average have a weak content knowledge of mathematics (Ball, 1990; NCTAF, 1996). According to Desimone et al. (2006), teachers' having strong content knowledge is essential for students' achievement in mathematics. Research has shown that teachers who are not familiar with the topics they teach often convey misconceptions (Hashweh, 1987). Carlsen (1990) stated these teachers talk longer and more often, and tend to pose questions of low cognitive level. When looking at content focus professional development, it was found that teachers who have strong content knowledge in mathematics were more likely to participant in a sustained content focused professional development than those who had medium to low content knowledge (Desimone et al, 2006).

One of the findings of this study was that the content focused professional development was benefiting teachers with high content knowledge rather than aiding in closing the gap of those teachers with lower content knowledge. The teachers who face the biggest challenges in their classroom such as poverty and low achieving students are not participating in content focus professional development. Another finding was that teachers who feel less prepared, insecure about their abilities, or may have a negative attitude towards mathematics (Loucks-Horsley et al., 1999), are less likely to participate in a content focused professional development (Desimone et al., 2006). This research study concluded that teachers who may have the weakest content knowledge are not getting the best professional development. According to Desimone et al., (2006) teachers who have low content knowledge are less likely than the high or medium content knowledge teachers to participate in sustained content focus professional development.

Curriculum Focused Professional Development

Patel, Franco, Miura and Brian (2012), conducted a curriculum focused professional development study titled "Including Curriculum Focus in Mathematics Professional Development for Middle School Mathematics Teachers." This study has three central research questions:

1. Does participation in professional development focused on Connected Math significantly influence teachers' mathematical content knowledge?
2. Does participation in professional development focused on Connected Math significantly influence teachers' perceptions of their own pedagogical preparedness?
3. Does participation in professional development focused on Connected Math significantly influence teachers' attitude towards teaching mathematics (Patel et al., 2012, p. 302)?

Research has shown that there is a positive correlation between students' mathematics achievement and teachers' mathematical knowledge which refers to their computational abilities (Yoon et al. 2007). Content knowledge is just one aspect aiding in students' mathematical achievement. Early researchers Hill et al. (2005), however, examined the relationship between teachers' mathematical knowledge and their pedagogy as it relates to students' achievement; other research focused on the relationship of teachers' content knowledge (CK) and pedagogical content knowledge (PCK) in relationship to student achievement. Mathematical PCK deals with teachers' ability to understand and address students' common misconceptions of specific math content. It was found that there was a positive relationship between mathematics teachers' content knowledge and their pedagogical content knowledge aiding in greater student achievements. The Hill et al. (2005) study found that "students' achievement was greater when mathematics teachers have both content knowledge and pedagogical content knowledge" (Patel, et al., p. 300). To add evidence to support the idea that teachers' content and pedagogical knowledge affects students' learning, it was found that content knowledge had lower predictive power of students' learning than did pedagogical knowledge (Baumert, Kunter, Blum, Brunner, Voss, Jordan, & Tsai, 2010). This study also concluded that that pedagogical knowledge had a greater effect on instructional quality (Baumert et al., 2010).

The Patel et al. (2012) study consisted of one weeklong professional development workshops that were focused on a mathematics curriculum titled "Connected Mathematics Project (CMP)" in expectation that the workshops would help teachers to better understand the curriculum used in their classroom along with enriching their mathematical understanding of the content. Studies have shown that some of the elements of an effective professional development for mathematics teachers include time on mathematics content knowledge as well as on mathematics curriculum (Patel et al., 2012). Fuerborn, Chinn, and Morlan (2009) stated that middle-school mathematics teachers' understanding of content was increased using a curriculum based professional development. Curriculum materials are an essential tool used for instruction within each classroom. Thus, when teachers are familiar with the curriculum and content knowledge, these elements combined can result in the development of effective classroom lessons and consequently student achievement (Patel et al., (2012).

The results of Patel et al. (2012) research showed that it is possible to improve teachers' content knowledge when using curriculum focused professional development opportunities. All teachers in grades 6th-8th reported significantly higher content knowledge after their involvement in the curriculum focused professional development workshops. When it comes to teachers' perception of their own pedagogical preparedness, there were statistically significant changes noted in their abilities to provide concrete experiences, to allow students to work in collaborative groups, to allow students to engage in hands-on learning, and to use performance based assessments (Patel et al., 2012). Teachers in the study were "less likely to have positive attitudes about providing their students' with concrete experiences before abstract ones, about skills practice, about inquiry-based activities, and about mathematics applications in various contexts" (Patel et al., 2012, p. 305). Due to the small sample size of 7th and 8th teachers in the study, the results are not accepted with confidence. A similar qualitative study conducted by (Fryklom, 2005) on pre-service teachers concluded that curriculum based mathematics contributed to teacher shifts in attitude and beliefs about mathematics teaching, these findings confirm the results of this study. Teachers' content knowledge can be increased by using a middle school curricula aiding in deeper understanding of basic middle school mathematics content (Patel et. al., 2009). By teachers' focusing on the curriculum materials and students' thought process using the Connected Math curriculum, they would be better able to address students' misconceptions and develop sound pedagogical practices (Patel et. al., 2009).

Problem Solution based Professional Development

The research article titled "Problem Solved: Middle School Math Instruction Gets a Boost From a Flexible Model of Learning" (Jacobs, Koellner, & Funderburk, 2012) is focused on a problem solving professional development model. This model is called the Problem Solving Cycle (PSC) mathematics professional development, which was developed by Koellner, Jacobs, Borko, Schneider, Pittman, Eiteljorg, and Frykholm (2007), Jacobs et al. 2007, and funded by the National Science Foundation. It was implemented in Cherry Creek School District Fall of 2012. PSC is a school based professional development focused on developing professional learning communities (Jacobs et al. 2007). This professional development model was designed to help increase teachers mathematical knowledge in the areas of a) common content knowledge, b) specialized content knowledge, c) knowledge of content and teaching, and d) knowledge of content and students (Koellener et al., 2007). Mathematics teachers participated in a series of workshops during the semester focused on a particular math problem, followed by them being videotaped teaching the problem, then coming together to discuss, receive feedback, and reflect on the video clip. The teachers operate the problem solving professional development model within their school. One of two mathematics teachers are chosen to be leaders then trained to be facilitators of the PSC professional development. The problem solving professional development workshop for leaders consists of three workshops: a) a workshop to develop the content knowledge necessary to teach the PSC problem effectively in the classroom; b) a workshop on analyzing the role played by the teacher when implementing the PSC problem in the classroom; and c) a workshop on analyzing student thinking in terms of the mathematics of the PSC problem. Teacher-leaders, the research team, and the district mathematics coordinator worked together to learn the nuts and bolts of the problem-solving cycle professional development program. The teacher-leaders begin to implement the problem solving cycle within their school once they have been trained for one full semester, followed by a weeklong summer academy. The research team works with the school district for three years, then district coordinators take over with the research team offering minimum input and support. After the third year of implementation, it was found that there was a significant improvement on the participating teachers' mathematical knowledge. There was no other data offering evidence of the effectiveness of the problem solving cycle professional development model (Jacobs et al., 2012).

Online Professional Development

O'Dwyer, Masters, Dash, De Kramer, Humez, and Russelle (2010) conducted an online professional development study, the title of the research article was "e-Learning for Educators-Effects of On-Line Professional Development (OPD) on Teachers and their Students: Findings from Four Randomized Trials." This online Professional Development (OPD) has been developed to address the current interest to improve access, convenience, and cost of professional development. Even though there is an increased interest in OPD for the past decade, there is not a lot of scientifically-based research offering evidence of the impact of OPD on teacher and students' outcomes. To aid in the lack of empirical evidence, O'Dwyer et al. (2010) conducted four Randomized controlled trials focusing on the effect of OPD on teacher knowledge, teacher practice, and student achievement (O'Dwyer et al., 2010). In their research model, there was a control and a treatment group. The control group did not receive any OPD unless they were already receiving some other kind of professional development from their school. The treatment group participated in three series of OPD workshops. The timeline for the workshops extended over a seven-week period and required the teachers to participate between 4 to 6 hours per week. The study focused on ELA and Mathematics. This paper will only expound on the workshop components of the 5th and 8th grade mathematics content. Those components were as follows: 5th grade teachers' instructional practices in the area of algebraic thinking, fractions and measurement portions; 5th grade teachers' knowledge in the areas of algebraic thinking, fractions, measurement and composite math portions along with students outcomes in these areas after treatment (teachers' received OPD); 8th grade teachers' instructional practices in the areas of proportional reasoning, geometric measurement, and functions; 8th grade teachers' knowledge in the areas of proportional reasoning, geometric measurement, functions, and composite math along with students outcomes in these areas after treatment (teachers' received OPD). The results showed strong evidence that the participation of three coordinated series of OPD workshops has positive effects on teachers' instructional practices and content knowledge. A statistically significant effect was found for at least one student measure. The results of the trials of three OPD workshops can have positive effects on students' outcomes (O'Dwyer et al., 2010).

Formative Assessment Professional Development

McGatha, Bush, and Rakes (2009) conducted a year-long Formative Assessment in Middle School Mathematics (FAMM) which was created and implemented by the Center of Research in Mathematics and Science Teacher Department at the University of Louisville. According to William and Thompson (2008), five key strategies help to effectively implement a formative assessment of teachers' professional development. Provider must

1) Clarify, share, and understand goals for learning and criteria for success with learners.
2) Engineer effective classroom discussions, questions, activities, and tasks that elicit evidence of student learning.
3) Provide feedback that moves learning forward.

4) Activate students as owners of their own learning.
5) Activate students as learning resources for one another (p. 64).

Black and William (1998) conducted a meta-analysis of 250 studies examining the effect of formative assessment studies. Formative assessment can produce significant and often substantial learning gains when implemented with fidelity. Two research questions out of five were aligned with this study: 1) to what extend did the professional development experience have an impact on teachers' knowledge of mathematics, particularly with respect to rational numbers? 2) to what extend did the professional development experience have an impact on their students' knowledge of rational numbers? (p. 35). The sample of 20 (7 sixth, 6 seventh, and 7 eighth grade) experimental middle school mathematics teachers who received the FAMM professional development from 16 school districts were matched to control teachers (not receive FAMM professional development) by grade levels taught and types of classes. Teachers' data were pre and posttest assessment scores on a) an attitudes inventory and an efficacy inventory b) teachers assessment on rational numbers; and c) observation data from two lessons of each teacher. The student sample consisted of 321 students in the control group (6^{th}-87, 7^{th}-96, and 8^{th}-138) and 334 students in the treatment group (6^{th}-98, 7^{th}-127, 8^{th}-109). The students' pre-post assessment containing released fourth-and eighth grade rational number items from the National Assessment of Educational Progress (NAEP) was used.

The Formative Assessment in Middle School professional development (FAMM) consisted of thirty hours of summer institute (six hours for five days), and an additional thirty hours of monthly meetings throughout the year. These meetings took the form of large meetings after school with all teachers and leaders. Other times, the meetings consisted of a small group, including five or six teachers from several schools and one leader. The professional development was designed to incorporate strategies that have been proven to be effective through research. The strategies consisted of

> teachers engaged in small group activities and discussions, analyzed video and written case studies of mathematics teaching, analyzed written student work and videos of students' interviews, completed self-assessments of their own formative assessment practices, and wrote professional growth plans to guide their work during the school year (McGatha et al., 2009, p. 34)

The results of this study found that the professional development had an impact on teachers' cognitive level of questioning, use of peer assessment, and types of questioning strategies. Conflicting results appeared, however, between treatment and control students' performance outcomes. On one hand, the study showed that growth occurred in all the grades and groups. The largest gain was with the 7th grade experimental group who outperformed the control group. On the other hand, when looking at the 6th and 8th grade student performances, the control groups outperformed the treatment groups. The explanation given for the 7th grade performance was that the 7th grade experimental teachers used more level 3 depth of knowledge (DOK) questioning skills than the control group of teachers.

After evaluating the results from the five alternative professional development models, there is still a need for more empirical data-driven research to aid in offering research proven professional development characteristics ensuring students' gains. According to Santagata, Kersting, Givvin, and Stigler (2011) to move students beyond superficial mathematical understanding, teachers must possess a deep understanding of the subject matter and ways of teaching students to understand mathematical ideas. Teaching students also requires being able to recognize students potential along with having the ability to reach all students (CMST, 2000).

Since these skills and knowledge are developed through teaching and professional development, teachers cannot fully acquire them during their credential preparation (Santagata et al., 2011). Sustained professional development (PD) is essential in improving the quality of teaching along with aiding teachers in developing the complex skills needed to improve student learning (Darling-Hammond, 1996; U.S Department of Education, 2001, 2002).

Justification for using Meta-Analysis Methodology

A quantitative synthesis of the previous literature will be very useful with the emergence of empirical evidence supporting the notion that effective professional development learning opportunities can lead to gains in teachers' content knowledge, pedagogical knowledge and student outcomes. To this end, a meta-analysis will be conducted in this study and effect sizes will be computed to examine the effect of professional development programs components (duration, content, and intervention) on students' achievement in the selected studies.

Effect Size and Interpretation

Cooper (2009) defined effect size as the "magnitude of difference or relationship strength (p.161)." Card (2009) stated that "the magnitude of the effect size influences the likelihood of finding statistically significant results (statistical power)" (p. 85). In 1988, Jacob Cohens presented the standard definition of effect sizes.

> Without intending any necessary implication of causality, it is convenient to use the phrase "effect size" to mean "the degree to which the phenomenon is present in the population," or the "degree to which the null hypothesis is false." By the above route, it can now readily be clear that when the null hypothesis is false, it is false to some specific degree, i.e., the effect size (ES) is some specific non-zero

value in the population. The larger this value, the greater the degree to which the phenomenon under study is manifested. (pp.9-10)

The Pearson Correlation (r) and Cohens' (d)

There are three families of standardized effect sizes: the standardized mean difference, the correlation coefficient, and the odds ratio. Since these three measures are standardized they allow for comparisons between effects of different outcome measures of studies that are not on the same scale (Valentine & Cooper, 2003). The most common measures of effect sizes (ES) are the Pearson Correlation (r) and Cohen's (d) (Card, 2009). Both Cohen's (d) and Pearson (r) are scale free measures. The main difference between Cohen's (d) and Pearson Correlation (r) is that (d) is used to measure the separation of two means whereas (r) is used to assess the degree to which two variables are related (Valentine & Cooper, 2003). The Cohen's (d) will be used in this study as the measure of effect sizes. It represents "the magnitude of difference between the means of two groups as a function of the groups' standard deviation" (Card, 2009, p.90). Effect size is a standardized measure of the magnitude of observed effect (Field, 2005a). This allows the opportunity to compare effect sizes across different studies that may have measured different variables, or have used different scales of measurement. The guidelines for interpreting the magnitude of the effectiveness of a study are as follows: d=0.20 is considered a small effect, d=0.50 considered a medium effect, and d=0.80 considered a large effect (Field et al., 2005). For example, if d=0.20 (small effect), the interpretation of this result is that the means of the two groups differ by two tenths of a standard deviation. In other words, the mean of the intervention group lays two tenths of a standard deviation to the right of the non-intervention group. (Cooper, 2009)The larger the effect size the stronger the effect that one variable has on another (Card, 2009).

History of Meta-Analysis

The early 1900s was the beginning of scientists attempting to combine statistical results from multiple studies. Karl Pearson in 1904 was one of the early researchers to attempt to synthesize association between inoculation and typhoid fever. Many other scientists in the mid 1900's used different methods to synthesize studies. One of the approaches used around 1940's and 50's was the method of combining probabilities. Even with these new methods of combining statistical results, it took until the late '70s before the term "meta-analysis" and its methodology were accepted into the social science community (Card, 2012). In 1976, Glass and colleagues introduced the term "meta-analysis" (Glass, 1976). It was defined as

> the analysis of analyses . . . the statistical analysis of a large collection of analysis results from individual studies for the purpose of integrating the findings. It connotes a rigorous alternative to the casual, narrative discussions of research studies which typify our attempts to make sense of the rapidly expanding research literature. (Glass, 1976, p. 3)

Finally in the early 80's books were published describing the process of conducting a meta-analysis. For the past 30 years, there has been an increase in the use of meta- analysis technique in the social sciences (Card, 2012). Meta-analysis, which is also called quantitative research synthesis, is often used with empirical data to summarize and compare results from various studies.

There are two reasons for research synthesis in the social sciences. First, the increasing pace of research in most areas of study is making it difficult for scholars to stay current on new findings. Often the areas of studies according to Card (2012) are in less need of further research but rather need to be organized and synthesized. Second, researchers should be able to reproduce studies, but this rarely happens due to slightly different methods, measures, and/or samples. The central principle in science is

> The advancement of scientific knowledge is based on systematic building of one study on top of a foundation of prior studies, the accumulation of which takes on understanding to ever increasing heights. A closely related trend is replication- that findings of studies are confirmed (or not) through repetition by other scientists (Card, 2012, p. 3).

A meta-analysis (quantitative synthesis) approach in research, allows scientists to organize existing research of studies, systematically reviewing results, and summarize and compare results of the studies. A more formal definition of meta-analysis is “a methodological and statistical approach to drawing conclusions from empirical literature” (Card, 2012, p. 4).

Limitations of Meta-Analysis

This approach to synthesizing research findings was adopted in the field of psychology first, but it was not without controversy. There are no flawless experiments (Cooper, 2003). Further thought on this issue argues there are no flawless studies (Card, 2012); conducting a meta-analysis will not be exempted from this matter (Card, 2012). The limits that are encountered when conducting a primary study will be faced when using a meta-analysis technique. There are certain limitations that will be taken into account due to potential threats when drawing conclusions from empirical research. According to Card (2012) these limits are in the areas of study design, sampling, methodological artifacts, and statistical power.

One limitation of study design is that the extent of conclusions of the study is based on the type of study that is conducted such as experimental, quasi-experimental, and naturalistic (correlational) design. One limitation of experimental design is that whatever threats to the internal validity exist within the studies will be the same threats when the studies are combined in a meta-analysis. The limitation of the naturalistic design (correlational) is that it will only show the associations between variables and does not answer questions of causality.

A sampling threat is the limitation of generalizability. For example when looking at a homogeneous group meaning same characteristics such as the gender or ethnicity, etc., the results in the study can only be generalizations to that specific group.

There are methodological artifacts limitations that can either accentuate or diminish the statistical power of the effect size in the results of a study. Examples of these artifacts are imperfect reliability or validity, sampling homogeneity, or poor data-analytic choices (Card, 2012). When the effect size is accentuated this causes lower statistical power (higher rates of type II errors).

The last limitation that will be discussed is the limits of statistical power. The question is what is statistical power? Statistical power indicates the probability of concluding that an effect exists (Card, 2012). Sample size is key when examining statistical power, the larger the sample size, the greater the statistical power of the study. Primary studies often have low statistical power due to small sample sizes. However, since meta-analysis combines the results of numerous studies whether sample size is large or small, it tends to have a greater statistical power than the primary studies used in the meta-analysis (Card, 2012).

Figure 1: Theoretical Orientation and Conceptual Framework

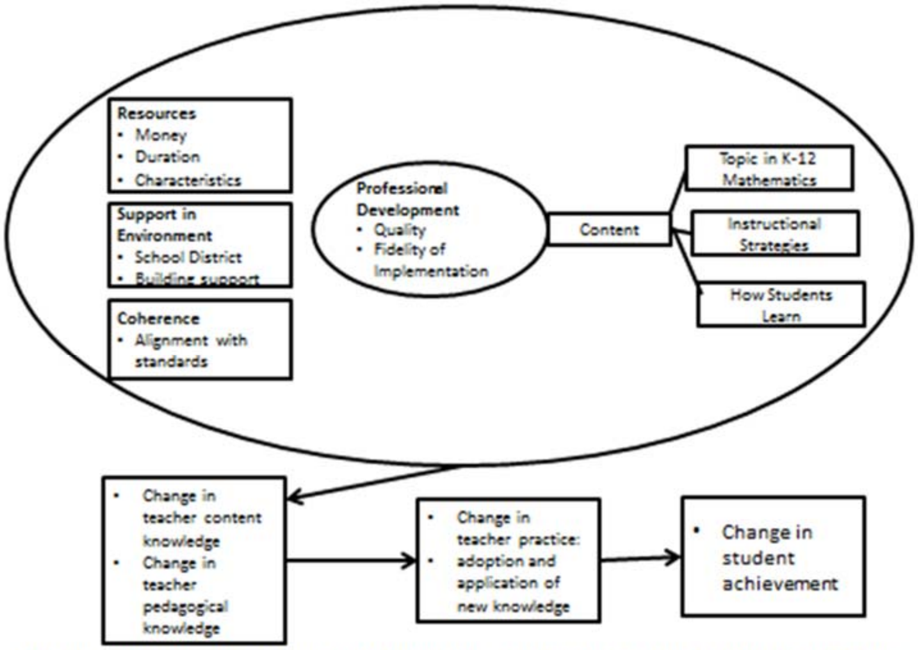


Figure 1. Theoretical Framework showing how features of professional development influences teachers and students outcomes. Scher, L., & O'Reilly, F. (2009). Professional Development for K-12 Math and Science Teachers: What Do We Really Know? Journal of Research on Educational Effectiveness, 2, 209-249., use under fair use, 2015.

Theoretical Orientation and Conceptual Framework

The conceptual framework of this study, consisting of the components in Figure 1, shows the theoretical sequence of features of professional development that will be used to analyze the effect of professional development programs (Scher & O'Reilly, 2009). The top portion of the diagram shows the components that are involved in creating and carrying out a professional development program (Scher & O'Reilly, 2009). There are five components (resources, support in environment, coherence, quality and fidelity of implementation, and content (topic, instructional strategies, and how students' learn) that are essential for an effective professional development program. Resources which include cost, duration, and characteristics of intervention (workshops, coaching etc.) are extremely important factors in a professional development program. The intervention should be aligned with the state standards, and it is supported within the school community and/or district (Scher & O'Reilly, 2009). The center of the diagram shows that professional development should be good quality, and the implementation of the intervention should be as intended (fidelity of implementation). The left side of the diagram shows that the content of the professional developments should include mathematics, instructional skills, and focus on how students learn. The diagram also shows that there are three expected outcomes from this effective professional development model. The first outcomes of the intervention are expected to change teachers' content knowledge and their pedagogical knowledge. These changes are expected to lead to changes in teachers practice such as adoption and application of new knowledge (Scher & O'Reilly, 2009). Once there has been a positive change in teachers' content knowledge and pedagogical knowledge along with them buying into the intervention demonstrating changes in their teaching practice as they apply the new learned knowledge within their classroom, then this will promote change in students' achievement. According to Scher & O'Reilly (2009), this theoretical model will hold, if there is the assumption that there is a clear link between teacher knowledge, teacher practice, and student achievement.

Previous empirical research has proposed similar models (Cohen & Hill 2000; Hanssen, 2006; and Weiss & Miller, 2006) of exploring the relationship between teacher knowledge, teacher practice and student achievement (Scher & O'Reilly, 2009). The model in Figure 1 suggests that students' achievement is predicated on teacher knowledge and teacher practice; no improvement in teacher knowledge leads to no improvement with students' achievement. It is a consensus among the experts that teacher knowledge is critical. According to Scher & O'Reilly (2009), there has been some empirical research attempting to link teacher knowledge with student achievement, but the type of content knowledge needed is not clear. They also reported that "knowledge can be in the form of specific math content knowledge, pedagogical knowledge (an understanding about how students learn), and pedagogical content knowledge, which is the measure of understanding the content needed for teaching the topic" (p. 211). Thus, even though teachers' subject matter knowledge is considered crucial to improve student achievement, it is often debated among researchers which knowledge should be emphasized (Weiss & Miller, 2006). In addition, there is a lack of strong empirical evidence linking teachers' content knowledge and student achievement due to a paucity of good measures on teachers' content knowledge and practice (Scher & O'Reilly, 2009). However, there have been some suggestions by experts in the field which combine theory, practical knowledge, and empirical evidence in offering guidance about how professional development should be structured and conducted from K-12 mathematics teachers (Scher & O'Reilly, 2009).

The American Educational Research Association (AERA, 2005) Research Points review suggested that professional development designed to link teacher learning and change in classroom practices will lead to higher student achievement. PD should be content focused, aligned with teachers' real work experiences and curriculum. It should be allotted adequate time and duration, to include opportunities for observing and analyzing students' understanding of the subject matter. Elmore (2002) offered recommendations for components of an effective professional development. These seven components have been accepted as the norm among practitioners. According to Elmore (2002), effective professional development should: a) have clear goals that are anchored in student learning of core discipline and skills; b) focus on issues of curriculum and pedagogy; c) be based on well-articulated theories or models of adult learning; d) involve staff and school leaders; e) take place over an extended period for continuous; f) improvement; g) provide models of effective practice, and h) use assessment and evaluation to measure change (Elmore, 2002, p.7).

The recommendations offered by AERA (2005) and Elmore (2002) are largely based on theoretical and practical advice rather than empirical evidence. However, without offering empirical evidence when suggesting elements of an effective professional development, it is difficult to assess the importance of each characteristic and the magnitude of the effect of different elements of the professional development model (Scher & O'Reilly, 2009). On the other hand, Desimone (2011) stated that there has been a consensus on the main components of effective professional development in empirical research that is associated with "changes in knowledge, practice, and to a lesser extent student achievement" (p.69). These components of professional development are content focus, active learning, coherence, duration, and collective participation.

One of the goals of this research is to fill some of the gaps in the literature to provide evidence based support for different components of the PD. This research is guided by the ideas of effective professional development components, teachers' math content knowledge, subject matter knowledge, and teachers' pedagogical knowledge as each of these is likely to have an impact on student achievement.

Teachers' Knowledge

Before addressing the different views on teachers' math content knowledge, subject matter knowledge, and pedagogical content knowledge and their effect on student learning, there is an unresolved issue about the organization of teacher's knowledge. The organization, composition, and characteristics of teachers' knowledge have not been agreed upon (Hill et al., 2005). Researchers have made conjectures about the organization of teachers' knowledge, which has been useful in the educational research community. Shulman (1986) purposed three categories of teacher subject matter knowledge. The categories were content knowledge, pedagogical content knowledge, and curriculum knowledge (Hill et al., 2004). Leinhardt and Smith (1985) identified two components of knowledge for teaching: lesson-structure knowledge and subject-matter knowledge. In 1990, Grossman reorganized Shulman and colleagues' categories of subject-matter knowledge by extending them into four categories: subject-matter knowledge, general pedagogical knowledge, pedagogical content knowledge, and knowledge of context. In addition, Ball (1990) identified two dimensions in teachers' content knowledge. These dimensions were the knowledge of mathematics and the knowledge of doing mathematics. Lastly, Ma's (1999) study compared U.S. and Chinese elementary teachers to explain and contrast the connectedness, perspectives, fundamental ideas, and longitudinal coherence that occurred during their teaching. The work of researchers as they proposed potential categories of content knowledge has contributed to the development of theory about teachers' content knowledge (Hill, Schilling, & Ball, 2004).

Teachers' Math Content Knowledge

Scholars agree that math content knowledge is critical for all mathematics teachers to be able to teach mathematics to students. Consequently, there is a lack of agreement on what type of knowledge teachers' need to know to teach children mathematics; and how to measure teachers' knowledge (Hill et al., 2004). These debates are on-going and are reflected in theoretical and empirical research literature when different elements and organization for such teaching knowledge are suggested. Some authors suggest that general mathematics is an important qualification (U.S. Department of Education, 2002). Others suggest that teachers' general mathematics ability is not enough. Teachers must possess the knowledge that is required to understand students' thinking about content as well as the pedagogical content knowledge that is required to teach mathematics (Hill et al., 2004).

Some argue the mathematical knowledge needed for teaching is neither adequately reflected in the number of math courses one has taken nor is it adequately reflected in their basic mathematical skills (Hill et al., 2005). In math education research, scholars have shown that the amount of mathematical knowledge needed to teach children is much different from what would be acceptable for other adults when teaching fractions, place value, or slope (Hill et al., 2004). According to Hill et al. (2005), teachers must be able to understand the mathematics they teach as well as use their subject matter knowledge to carry out the tasks of teaching. In addition, they should have a depth of knowledge allowing them adequately explain mathematical concepts along with the ability to analyze students' thinking, solutions, and explanations during instruction (Hill et al., 2005). With the limited amount of empirical studies available to help judge and validate the type of mathematical knowledge needed to teach children the debate continues (Hill et al., 2004).

Another disagreement among experts is the measures that are used to evaluate teachers' knowledge. In research literature, many different proxy variables have been used to measure teachers' knowledge such as courses taken, degrees earned or results of basic skills exams (Hill et al., 2005). According to Hill et al. (2005) teachers' knowledge has not been measured accurately. With this claim, the current research findings in regards to the magnitude and effect of teachers' knowledge on students' learning and the kinds of teachers' knowledge needed to increase student gains could be limited in terms of its conclusions (Hill et al. 2005).

Educational research is limited when it comes to assessing the relationship between teachers' mathematical knowledge and student achievement (Hill et al., 2005). In a study that offered empirical evidence on the impact that teachers' mathematical knowledge has on student achievement (Hill et al., 2005), teacher mathematical knowledge was defined as "the mathematical knowledge used to carry out the work of teaching mathematics" (p.373). The term "work of teaching" mathematics consist of explaining terms and concepts, interpreting students' thinking and assignments, evaluating and supplementing textbook treatments of particular topics, accurately teaching mathematics concepts in the classroom and providing students with examples of mathematical concepts (Hill et al., 2005,). The results of this study added empirical evidence showing that first and third grade teachers' mathematical knowledge was significantly related to students' achievement after controlling for key teacher and student level covariates. Even with this positive evidence, there is no prescription for the type of mathematics content knowledge teachers need to know to teach (Hill et al., 2004).

Shulman et al. (1986) purposed three categories of subject matter knowledge. The categories were content knowledge, pedagogical content knowledge, and curriculum knowledge (Hill et al., 2004). They believed that the effectiveness of teachers depended on two important components, which includes teachers' knowledge of the content and their knowledge of how to teach the concept (Hill et al., 2005). Shulman and his colleagues' (1986) content knowledge category emphasized knowledge of the subject and its organization. Pedagogical content knowledge (PCK) includes an understanding of what is difficult or easy for students to learn as well as articulating the specific content ideas (Hill et al. 2005). Lastly, curriculum knowledge involves attentiveness to the arrangement of topics throughout the school year and connecting to future school years as well as using available school resources such as textbooks and organized a supplemental program of study for students (Hill et al. 2005).

In 1987, Shulman no longer considered pedagogical content knowledge (PCK) as a subcategory to teachers' knowledge; it was considered to be equal with "content knowledge, general pedagogical knowledge, curricular knowledge, knowledge of learners, knowledge of educational context, and knowledge of philosophical and historical aims of education" (Gess & Lederman, 1999, p. 4). PCK was defined as

> that special amalgam of content and pedagogy that is uniquely the providence of teachers, their own special form of professional understanding…Pedagogical content knowledge…identifies the distinctive bodies of knowledge for teaching. It represents the blending of content and pedagogy into an understanding of how particular topics, problems of issues are organized, represented and adapted to diverse interest and abilities of learners, and presented for instruction. Pedagogical content knowledge is the category that is most like to distinguish the understanding of the content specialist from that of the pedagogue (Shulman, 1987, p. 8).

Pedagogical content knowledge has been of extreme interest in the research community and with practitioners, since its origination (Gess et al., 1999). Later Grossman (1990) developed the notion of professional knowledge for teaching. She reorganized Shulman and colleagues categories of subject matter knowledge by extending them into four categories. The four categories were subject-matter knowledge, general pedagogical knowledge, pedagogical content knowledge, and knowledge of context. She defined pedagogical knowledge as having four components: "the conception of purpose of teaching subject matter, knowledge of students' understanding, curricular knowledge, and the knowledge of instructional strategies" (Comeaux, 1991, p. 379). PCK was anticipated to have the most impact on teachers' classroom practice than the other three knowledge bases (Gess et al., 1999).

Until the research conducted by Hill et al. (2005), no empirical evidence existed linking teachers' usable professional knowledge of their subject to student achievement. This study reported that most of the research literature that was based on the foundation of teacher knowledge has been qualitative in nature relying on case studies (Grossman, 1990), expert-novice comparisons (Leinhardt & Smith, 1985), and international comparisons (Ma, 1999), along with studies on new teachers (Ball, 1990). No general consensus existed on the type of teacher knowledge that is needed to impact student gains in mathematics.

Hill, Rowan, and Ball (2005) examined the relationship between teacher's mathematical knowledge and their pedagogy as it relates to students achievement; other research focused on the relationship of teachers' content knowledge and pedagogical content knowledge (PCK) in relationship to student achievement. Mathematical PCK deals with teachers' ability to understand and address students' common misconceptions of specific math content. It was found that there was a positive relationship between mathematics teachers' content knowledge and their pedagogical content knowledge and student achievement. It is important for mathematics teachers to have both (Patel et. al., 2012). All experts in the mathematics-teaching field, agree that math content knowledge is important but the problem lies with teachers that may know the mathematics but cannot teach it to children. Good effective mathematics teachers' classroom practices should include the incorporation of both teachers' content knowledge and pedagogical content knowledge. This research will examine what professional development models lead to changes in teacher content knowledge and pedagogical content knowledge.

A meta-analysis will be conducted in this study using rigorous empirical research studies to offer evidence from current research about elements of an effective professional development models that influence teacher knowledge, teacher practice, and student achievement.

Summary

Although teachers' content knowledge and teachers' pedagogical knowledge are considered important, it is not clear how they are linked to each other and how professional development should be structured to address those knowledge gaps (Even, 1993). Furthermore, in 2007, a meta-analysis was conducted by the Council of Chief State School Officers to examine the effects of teacher professional learning on raising student achievement (Blank & de las Alas, 2009). This study focused on program design and implementation of professional learning that had a significant impact on students' learning. Consequently, multiple and continuous activities designed to reinforce and follow-up with teachers were the most effective programs (Blank, 2013). The study also concluded teacher professional learning that includes "content focus, longer duration, multiple activities, hands-on teacher learning, specific learning goals, and collective teacher participation has a significantly better chance to improve teacher skills and knowledge and, subsequently, to raise student achievement" (Blank, 2013, p. 53). For students to meet the high standards that the federal government, states and school districts have adopted, it is important to provide teachers with effective professional development. This will aid in improving teacher's content and pedagogical knowledge along with increasing students' mathematics achievement. A meta-analysis methodology will be used to evaluate effect size showing the impact of professional development components (duration, content, and intervention) on students' achievement. This study will explore whether effect size varies depending on the type of professional development program (content versus pedagogical focus); duration of the program (1 year versus multiple years); and program components (workshop only, workshops and coaching, or workshops and other components) (Scher & O'Reilly, 2009).

Chapter Summary

This chapter is an overview of current research studies on the effect of professional development for K-12 mathematics teachers and student achievement. The topics covered in this chapter are 1) the importance of professional and history of professional development 2) the characteristics of an effective professional development models; 3) the need for rigorously designed professional development models; and the justification for using the meta-analysis methodology to evaluate effect size showing the impact of professional development components (duration, content, intervention) on students' achievement.

Chapter 3: Methodology

Research Design

Meta-analysis, which is also called quantitative research synthesis, is a specialized form of statistics analysis that was used in this study to combine results of many studies conducted on K-12 professional development programs. The purpose of this research is to summarize, compare, and integrate the results of empirical literature offering a comprehensive assessment of the impact of professional development programs on K-12 mathematics teachers and student achievement.

A meta-analysis methodology will be used to evaluate effect size showing the impact of professional development components (duration, content, and intervention) on students' achievement. This study will explore whether effect size varies depending on the type of professional development program (content versus pedagogical focus); duration of the program (1 year versus multiple years); and program components (workshop only, workshops and coaching, or workshops and other components) (Scher & O'Reilly, 2009). This chapter will explain in detail the type of procedures involved in conducting a meta-analysis. These procedures include data collection (searching literature), analysis of data (coding), interpreting results, generalizability and a summary of the four statistical measures used in the study. There are some critical issues that are addressed when using this type of methodology such as study coding, effect size computation, and validity.

The meta-analysis of the effects of professional development programs on K-12 mathematics teachers and student achievement was conducted. Sixteen samples of K-12 professional development programs studies were collected followed by coding features of each study. In addition, the effects for each study were computed and combined, followed by individual variables being examined.

Justification for Sample Size

There is no set number for the quantity of studies that are needed when conducting a meta-analysis but there should be enough studies available to "provide complementary information that is valuable to other researchers, clinicians, or policy makers" (Walker, Hernandez, & Kattan, 2008, p. 438). Even though there has been a large amount of research describing best practices in professional development, there is relatively little research on the effects of alternative forms of professional development and students' achievement (Garet et al., 2001). In support of the 16 studies being an ample sample size for a meta-analysis in 2007, the scholars from the American Institute for Research analyzed 1343 studies that potentially addressed the effect of professional development on students' learning and only nine studies were included in their report "Reviewing the Evidence on How Teacher Professional Development Affects Student Achievement" (Yoon. et al., 2007). In addition, Scher and O'Reilly (2009) conducted a meta-analysis evaluating K-12 math and science professional development programs (interventions) that took place in the United States from 1990 to 2004. In their search for literature to meet the inclusion criteria, 145 evaluations of K-12 math and/or science professional development programs (interventions) were reviewed with 41 studies being considered potential inclusions but only 18 studies qualified. There were seven math focused programs, three math and science programs, and eight science programs included in the study. Both Yoon et. al. (2007) and Scher and O'Reilly (2009) studies have added valuable information to the educational research community in regards to the impact of K-12 mathematics programs (interventions) on student learning. Therefore, when conducting analysis in this study, the most appropriate statistical processes were used to make comparisons among the studies' effect sizes to answer the following questions:

1. What is the average impact of rigorously evaluated recent professional development programs on math student achievement?
2. Among these rigorously evaluated programs, how do these effects vary? Do programs that incorporate the characteristics that have been asserted through theory and practice to be particularly beneficial to professional development programs have stronger effects than programs that do not? (Scher & O'Reilly, 2009, p.217)

The variables (duration, content, and intervention) and research questions were examined in Scher and O'Reilly (2009) meta-analysis study that spanned from 1990 thru 2004. This study will focus on new empirical research findings on the impact that K-12 mathematics teachers' professional development have on students' achievement from 2003-2014.

Approach to Research

Identifying the Problem

There is a huge difference when choosing a topic for study in a primary study compared to a meta-analysis. In a primary study, the choice of a topic is only limited to your imagination but when conducting a meta-analysis, there is dependence on the research literature (topics) that are already available (Cooper, 2009). When formulating a problem to investigate in a meta-analysis, it is important to study a topic that has sufficient interest within the discipline offering ample research literature to be able to bring it all together (Cooper, 2009). The beauty in formulating problems when using the research synthesis approach is being able to propose overarching schemes that help summarize related studies and their outcomes. Scher and O'Reilly (2009) investigated the impact of K-12 professional development programs on mathematics teachers and students' achievement from 1990-2003. This time period is inclusive of the adoption of NCLB Act (2001). With the Institute of Education Sciences (IES) changing the educational research focus from developmental, descriptive, and survey based research toward inquiries built around random assignment studies along with the adoption of NCLB (U.S. Department of Education, 2002; Hill et al., 2013), it is befitting to investigate the literature from 2003-2014 on impact of K-12 professional development programs on mathematics teachers and students' achievement. This will offer support of impact based on more rigorously designed studies.

Literature Search Procedures

The search for empirical literature for this study will be limited to K-12 mathematics professional development intervention programs. Literature searches included computer searches, journals, dissertations, and conference papers. The key descriptors that were searched through different educational data bases (EBSCOhost, ERIC, Teacher Reference Center, APA PsycInfo, ERIC ProQuest, Springer Link, and Google) were professional development and math teachers; professional development and math teachers and student achievement; professional development and math achievement; professional development and math content knowledge; professional development and pedagogical knowledge and teacher quality; professional development and math teacher and pedagogical knowledge; professional development and math teacher and pedagogical and content knowledge and student achievement; and professional development for math teachers and education and student achievement (see Appendix A).

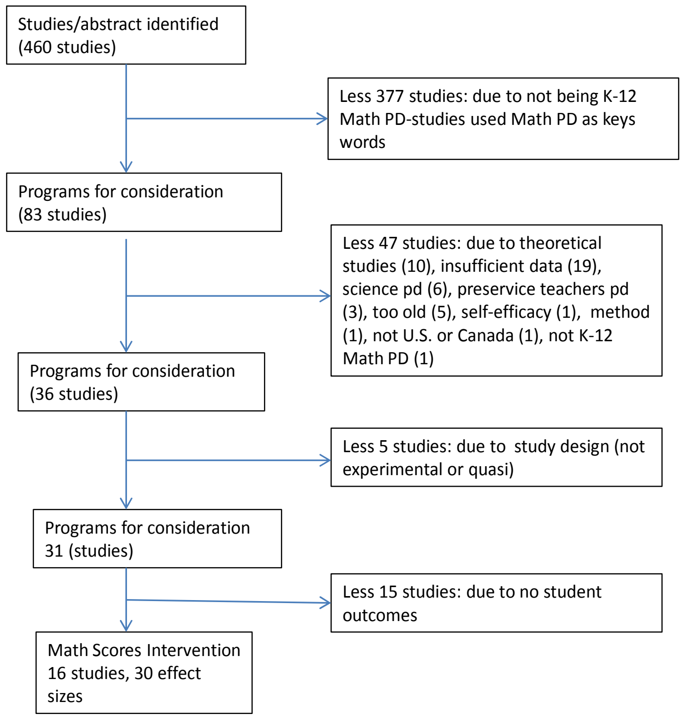


Figure 2. Number of studies included in meta-analysis of students' achievement outcomes.

Figure 2 displays the process that was used to document the number of studies reviewed and eventually included in the meta-analysis of the effects of professional development programs on students' achievement. There were a total of 460 studies identified using these data bases and key words (see Appendix B). A preliminary group of 83 studies were selected from all available studies to determine their appropriateness for inclusion in the meta-analysis. Of the 83 studies 67 studies were eliminated. When instrumenting the exclusion criteria some of the studies may have fallen into more than one category. These studies met some of the established inclusion criteria, with the exception of (see Appendix B):

1) The studies were not K-12 mathematics professional development-272:
    a. The words "math teachers" and "professional development" were mentioned in the study without professional development learning opportunities were offered.

b. Study focused on some form of professional development opportunities but was not aiming to increase teachers' mathematics content knowledge or pedagogical content knowledge or both.
c. Study was not focused on professional development models but offered suggestions that professional development was needed.
d. Study focused on the evaluation or assessment of professional development programs.

2) The study did not provide any data for student achievement (teachers' outcomes only)-182.
3) The study examined the theory of professional development with inadequate quantitative data-90.
4) The study provided qualitative data on student performance-48.
5) The study did not provide adequate statistical data for calculating effect size-40.
6) The study examined teachers' self-efficacy towards professional development-7.
7) The study examined teachers and students perception (beliefs) of teaching and learning-32.
8) The method or criteria used to conduct the study did not qualify (meta-analysis, study outdated, not conducted in United States or Canada, preservice teachers, or science)-60.

After a thorough review of all studies there were a total of 16 studies that qualified to be included in this study.

Publication Bias

There is some controversy as to whether unpublished literature and the literature that is considered grey literature should be included in meta-analyses. In addition, there are differences of opinions in regards to what is considered grey literature and its impact on the research synthesis process. For the purpose of this paper, it is defined as "all documents except journal articles that appear in widely known, easily accessible electronic data bases" (Cooper, Hedges, & Valentine, 1994, p. 105). Grey literature is often overlooked by research syntheses if only popular data bases are used when searching for literature to include in meta-analysis. Other reasons for exclusion including having some researchers believe that these types of studies may be incomplete and their methodological quality (validity) could be difficult to find (Schmucker, Bluemle, Briel, Portalupi, Lang, Motschall, Schwarzer, Bassler, Mueller, Elm, & Meerpohl, 2013). According to Cook, Guyatt, and Ryan (1993) it was found that 78% of authors of meta-analyses felt that unpublished studies should be included compared to the 47% of journal editors. It is of extreme importance that there is an attempt to find published and unpublished literature to reduce the impact of publication bias (Cooper et al., 1994). However, a thorough and systematic search of literature was done for this study which included efforts in finding relevant reports both published and unpublished (Card, 2009). The importance of decreasing publication bias is due to the fact that "studies finding null (absence of statistically significant effect) or negative (statistically effect in opposite direction expected) results are less likely to be published than studies finding positive effects (statistically significant effects in expected directions)" (Card, 2009, p. 257). According to Schmucker et al. (2013), there must be an attempt to find all articles whether published or not. If the missing studies differ systematically from the published ones, the assessment of the intervention's effects will be inaccurate and possibly lead to biased results from the meta-analysis.

The thorough literature search for potential studies to be included in the meta-analysis results showed that 7 out of 83 (8%) articles were unpublished conference papers. Authors of the seven conference papers were contacted through email requesting a copy of full research paper or any available data that they wish to share. Only authors of one conference paper responded stating that their study was a poster board presentation. They also sent a copy of their poster presentation. Another email was returned due to the address no longer being in service. There were a total of 9 (11%) dissertations found and available from the search. To satisfy the possibility of publication bias, this study has made every attempt to find published and unpublished studies on the impact of professional development programs for K-12 mathematics teachers and students' achievement.

Study Inclusion and Exclusion Criteria

The selection criteria that were established for this meta-analysis are listed:

1) The time period covered in the review: 2003-2014. (After the new reform with NCLB, 2001).
2) K-12 mathematics teachers professional development in the United States/Canada.
3) Published/Unpublished studies- dissertations, unpublished reports, conference presentations, reports to funding agencies.
4) Student outcomes must be included in study.
5) Rigorous Study-Pre-Posttest and or Treatment and Control group. Each primary study had a control or comparison group. This is 'essential,' when calculating the effect size,

which is the mean difference between groups in standard score form i.e. the ratio of the difference between the means to the standard deviation (Card, 2009.

6) Sufficient Quantitative Data-, the results in these studies had all provided sufficient quantitative data from which effect sizes can be calculated. In particular for each group: Sample Size (N), Mean (M) and Standard Deviation (SD). Studies must include enough information to compute an effect size, if there is no sufficient information-I should contact the author to request more information.

A critical synthesis of professional development literature was conducted, and a matrix (spreadsheet) was created to summarize the key elements of each paper. The matrix (spreadsheet) will consist of the papers' number, author(s), the publication date, title, source, abstract, article in possession or not, along with where and when article was found (date) (Card, 2009) (see Appendix C). Another matrix was developed to summarize the criteria qualifications for inclusion of meta-analysis (see Appendix D). The characteristics consisted of papers' number, author(s), publication date, K-12 mathematics professional development, content knowledge and or pedagogical content knowledge, published/unpublished, type of professional development (intervention), control/treatment group, data (N, M, and SD), and whether the study qualified for inclusion (see Appendix D). A critical synthesis of professional development literature was conducted and there were 31 out of 83 (37.3%) studies that used an experimental or quasi-experimental design to examine the effects of interventions on student achievement.

Coding Process

A coding manual was created for each study which included study identifiers, sample characteristics, measurement characteristics , design characteristics, and source characteristics (Cooper, 2009) (see Appendix E). Sample characteristics include sample size, sample age, sample grade, proportion of male, proportion of ethnicity, or any other unique characteristics such private or public schools. Measurement characteristics are represented by identifying sources of information, measurement process and specific measures (dependent variables and how they were measured, statistical outcomes and effect sizes) in the study. Design characteristics entailed the design type (experimental, quasi-experimental, pre-post comparisons, etc.). In addition, the source characteristics coding included whether the study was published or non-published, and year of publication (Card, 2009).

Even though the content of each study is unique, the coding manual will assist with gathering primary information for the synthesis (Cooper, 2009). It will also assist with reducing the amount of time rereading reports if the information that is included in the coding manual is carefully considered. Next the information from the 31 studies were coded using coding schemes of the quantitative data from each study concentrating on whether the needed components (sample size, mean, standard deviation for calculating effect sizes) were present so that comparisons can be made across studies (see Appendix F). It was found that 16 of the 31 (51.6%) studies meet all six inclusion criteria for the meta-analysis (see Appendix G). 5 out of 16 (31%) studies were dissertations. Two authors of dissertations were contacted by email requesting the needed missing data information in their study for calculating effect sizes. One author responded by sending the needed data. A coding manual was created for each study (Cooper, 2009).

There is an agreed stance among scholars that we need more empirically valid methods of studying professional development (Wayne et al. 2008). In support of the Institute for Education Sciences (IES), changing the educational research focus from developmental, descriptive, and survey-based research toward inquiries built around random assignment studies, these 16 studies will offer support to these concepts (U.S. Department of Education, 2002; Hill et al., 2013). The 16 studies used experimental or quasi-experimental designs to examine the effects of interventions on teachers and student achievement. A matrix including these studies was created summarizing the study number, authors' name, year of study, grade level, location, duration, content, intervention, sample size treatment/control, student treatment and control data, student pre-post outcomes data, effect size data, and effect size (see Appendix G).

Internal and External Validity of Study

Validity of a study is of extreme importance. The basic question is, is the study measuring what it is supposed to measure? There are two forms of validity that will be addressed in this study. The first is internal validity which refers to the extent in which the "study design allows for conclusions of causality from observed associations" (Card, 2009, p. 71). It basically addresses the validity of the measurement and test itself. For example, an experimental study (random sampling) has more interval validity than quasi-experimental studies using convenient sampling (Shadish, Cook, & Campbell, 2002). The second type of validity is external which refers to "the extent in which the findings from a particular study can be generalized to different types of samples, conditions, or different ways of measuring the constructs of interest" (Card, 2009, p. 71). When conducting research both of these are of extreme importance when analyzing the appropriateness, meaningfulness, and usefulness of a study.

According to Wilson (2009) there are two important characteristics of coding. Coding should be transparent and have replicability. By using a coding manual (guide) to document the detailed information in regards to how a research report is qualified to be included in the meta-analysis offers transparency to the study. This manual serves as documentation of the coding process that will guide the meta-analysis while offering a paper trail of evidence ensuring transparency of the coding (Card, 2009) (See Appendix E). This leads to the question of how reliable are the independent efforts of coding from the same studies. The Intra-coder agreement was used to assess the coding of a subset of two studies that were coded by two different coders after sufficient time had passed (Card, 2009). To ensure coding reliability, 2 out of the 16 studies were coded by two different people. To compute the percent of agreement, all codes for all studies were compared item by item (see Table 1). The agreement rate was 100%.

Table 1
Agreement Rate (AR)

$$AR = \frac{\text{No. of agreements}}{\text{No. of studies}}$$

- No. of agreements is the number of studies in which two coders provided the same categorical coding for this study characteristics.
- No. of studies is the number of studies that both coders provided score for this study characteristics.

Determining the Type of Effect Size to Use

Before determining the type of effect size to use, it was decided that the studies would be used as a unit in this research synthesis. This means that an overall decision will be made about the results reported in each individual study. For example, "if a study contains information on more than one test of the same group comparisons or relation, the synthesis can calculate the average of these results and have that represent the study" (Cooper, 2009, p. 110). Having one effect size per study offers an opportunity to make comparisons between them. Likewise, the ultimate goal of the meta-analysis process is to be able to integrate the results of each study's findings. According to Cooper (2009), effect size is defined as the "magnitude of difference or relationship strength" (p.161). Card (2009) states that "the magnitude of the effect size influences the likelihood of finding statistically significant results (statistical power)" (p. 85).

When comparing studies, it is often that the outcome measures used in studies that vary from one study to the next. To address this problem when doing a synthesizing data, a standardized effect size will be used. There are three families of standardized measures such as the standardized mean difference, the correlation coefficient, and the odds ratio. One of the important features when using a standardized effect size is that it allows for making comparisons between effects of studies that may not use the same scale for measurement. There are three indices that are commonly used when using the standard means difference method for analyzing data. These indices are Hedges' (g), Cohen's (d), and Glass index (g_{Glass}) (Grissom & Kim 2005; Rosenthal, 1994) (see Table 2).

Table 2

Standardized Mean Difference

Hedges's g:	$g = \frac{M_1 - M_2}{S_{pooled}}$
Cohen's d:	$d = \frac{M_1 - M_2}{Sd_{pooled}}$
Glass's Index: g_{Glass}	$gGlass = \frac{M_1 - M_2}{S_1}$
S_{pooled}:	$s = \frac{\sqrt{(x_i - \bar{x})^2}}{(n-1)}$
Sd_{pooled}:	$sd = \frac{\sqrt{(x_i - \bar{x})^2}}{n}$

- M_1 and M_2 are the means of Groups 1 and 2.
- S_{pooled} is the pooled estimate of the population standard deviation.
- Sd_{pooled} is the pooled sample deviation.
- S_1 is the estimate of the population standard deviation from Group 1 (Control Group).

The main difference among the three indices is the form of standard deviation that is used. Hedges'g and Cohen's (d) are basically the same with the exceptions of Cohen's (d) giving a biased estimation of the populations' standard deviation. This is mostly affected when the sample sizes are small. With modestly large sample sizes *g* and *d* are basically the same (Card, 2009). On the other hand, g_{Glass} (g) the standard deviation is based on the population estimate of one group (control). This index is used for therapy trials. It is found that the control group offers a better standard deviation than the therapy group. The drawback is that the primary studies must include the standard deviations for both groups, if not, you cannot derive g_{Glass} effect size from inferential statistics (e.g. *t*-test values) but you can compute *g* or *d* from these test (Card, 2009). If standard deviation of the two groups is equal (homoscedastic), then it would be fruitless to use g_{Glass} as an index for effect size. On the other hand, if standard deviations of the two groups are different (heteroscedastic), g_{Glass} would be a better effect size index to use compared to *g* or *d* (Card, 2009).

Interpretation of Results

Cohen (1977) developed the effect size statistics or *d* for typical behavioral sciences as a whole. In 1988, Cohen (1988) addressed some of the issues of interpreting these effect size estimates in relations to other effect sizes. According to Valentine et al. (2003) as in field of education where effect size may be smaller than others, Cohen warns that the relative effect size guidelines that he developed can be misleading. He suggested that they be used with caution and not used as a generic descriptor of the magnitude of effect size but should be based on effect size relations found in the field of study. "The most informative interpretations occur when the effect size is compared to other effects involving the same or similar variables" (Valentine et al., 2009). The guidelines are as follows: no effect d=0 and r=0, small effect d=0.20 or r=0.10, medium effect d=.50 or r=0.30, and large effect d=0.80 or r=0.50. The larger the effect size the stronger the effect that one variable has on another. These guidelines that Cohen (1977) developed should be used with caution. For the purpose of this study the standardized mean difference method will be used to calculate effect size (Cohen, 1988). The standardized mean difference Cohen's (d) (1988) effect size is a scale free measure of the separation between two groups means. Calculating d for any comparison involves dividing the difference between the two groups means by either their average (pooled) standard deviation or by the standard deviation of the control group. This calculation results in a measure of the difference between the two group means expressed in terms of their common standard deviation or that of the untreated population. Thus a d of 0.25 indicates that one-quarter standard deviation separates the two means (Valentine, et al. 2003, p 2-3).

Table 3

Cohen's (d) Interpretation

Cohen's Standard	Effect Size	Percentile Standing	Percent of Nonoverlap
Large	2.0	97.7	81.10%
	1.9	97.1	79.40%
	1.8	96.4	77.40%
	1.7	95.5	75.40%
	1.6	94.5	73.10%
	1.5	93.3	70.70%
	1.4	91.9	68.10%
	1.3	90.0	65.30%
	1.2	88.0	62.20%
	1.1	86.0	58.90%
	1.0	84.0	55.40%
	0.9	82.0	51.60%
	0.8	79.0	47.40%
Medium	0.7	76.0	43.00%
	0.6	73.0	38.20%
	0.5	69.0	33.00%
Small	0.4	66.0	27.40%
	0.3	62.0	21.30%
	0.2	58.0	14.70%
	0.1	54.0	7.70%
	0.0	50.0	0.00%

Cohen (1988) cautiously defined effect sizes as small, d = 0 to 0.49, medium, d = 0.50 to 0.79, and large, d ≥ 0.80, stating that there should be caution when offering conventional operational definitions for effect sizes for use in terms of power analysis in as diverse a field of inquiry as behavioral science. Effect sizes can also be interpreted as the average percentile standing of the average treated (or experimental) participant relative to the average untreated (or control) participant (Becker, 2000). For example the *d* (ES) of 0.0 indicates that the mean of the treatment group is at the 50th percentile of the control group while the *d* (ES) of 1.3 indicates that the mean of the treatment group is at the 90th percentile of the control group. Effect sizes can also be interpreted in terms of the distance of separation of the treatment group and control group. Thus the percent of overlap of the two groups is indirectly proportional to the *d* (ES). For example ES of 0.0 indicates that the distribution of scores for the treatment group overlaps completely with the distribution of scores for the control group, there is 0% of nonoverlap (Becker, 2000). This pattern is inferred in Table 3 (Becker, 2000).

What Works Clearinghouse (WWC) is one of the leading mechanisms in offering educators research-based evidence on what is working in the field of education. WWC evaluates programs, products, practices and policies in education aiding educators to make informed decisions on best practices in the field (IES, 2010). Valentine et al. (2003) suggested that Cohen's (d) is the most appropriate effect size measure for WWC to use based on the type of studies that they review. Since this study will be evaluating professional development programs' effectiveness, Cohen's (d) effect size index will be used. Such analysis will result in evidence of the effectiveness of the professional development program for K-12 mathematics teachers in increasing student achievement. The software that will be used to analyze the data collected in the meta-analysis process is the Comprehensive Meta-Analysis (CMA) program.

Data Collection Tools

With the primary focus of this meta-analysis being to evaluate the effect of an intervention on student outcomes, random trials were preferred ensuring that the interventions were assigned in an experimental fashion meaning that there was no important difference between the treatment and control group (Borenstein, Hedges, Higgins, & Rothstein, 2009).

Experimental designs often offer inferences of causality whereas quasi-experimental designed studies do not. Since there is a limited number of empirical studies within the area of professional development for K-12 mathematics teachers and its impact on student learning quasi-experiment designed studies were also include. Each primary study had a control or comparison group (pre-posttest and or treatment and control group). There were three mixed methods studies (quantitative and qualitative data including in one study) also included in this meta-analysis. The quantitative portion of these studies was either experimental or quasi-experimental design in nature. The setting for the studies is K-12 learning environments. The goal is to include published and if possible unpublished studies to avoid publication bias.

Studies were collected from the period of 2003-2014 using educational data bases such as EBSCOhost, ERIC, Teacher Reference Center, APA PsycInfo, ERIC ProQuest, Springer Link, and Google. The type of studies that resulted from these searches included dissertations, conference papers, and journals of educational organizations.

Data-Analytic Strategy

When deciding what statistical program to use to calculate and evaluate the effect sizes of the different professional development programs, the Comprehensive Meta-Analysis software (3.0 version) was chosen. According to Cooper (2009), the major packages such as SAS, SPSS, and STAT can be used to produce meta-analysis calculations. However, he recommends using a software program that is exclusive for conducting meta-analyses such as Comprehensive Meta-Analysis (CMA). Cooper (2009) states that CMA is the best choice for performing a meta-analysis due to the many available options offered for carrying out the analyses. CMA was developed by Biostat, Incorporated which was established in 1986. This company is composed of a team of statistical experts in the U.S. and the U.K. They develop statistical software in the area of power and analysis and meta-analysis. The company is funded by the National Institutes of Health Small Business Innovation Research (NIH/SBIR). According to Biostat (2015) CMA software has been rated as the world's bestselling program for Meta-Analysis with more than 10,000 users.

After the completion of the coding manual and the final quantitative data matrix with all necessary information for conducting a meta-analysis, the data base was developed with the statistical information that was needed from the 16 primary studies using Comprehensive Meta-Analysis Software Program to answer the following two research questions.

1. What is the average impact of rigorously evaluated recent professional development programs on math student achievement?
2. Among these rigorously evaluated programs, how do these effects vary? Do programs that incorporate the characteristics that have been asserted through theory and practice to be particularly beneficial to professional development programs have stronger effects than programs that do not? (Scher & O'Reilly, 2009, p. 217)

Chapter Summary

This chapter focuses on the methodology of the study. The meta-analysis process includes justification for sample size, identifying the problem, literature search procedures, publication bias, inclusion and exclusion study criteria, coding process, validity of the study, determining the type of effect size to use, interpretation of results, data collections tools and the use of Comprehensive Meta-Analysis software (CMA) for data analysis.

Chapter 4: Results

Introduction

The goal of this study is to provide a numerical synthesis of the effects of K-12 mathematics professional development on students' achievement based on evidence of prior studies conducted in the last decade. In addition, the impact of the components of professional development programs (duration, content, and intervention) on students' gains will be evaluated. This study will provide useable findings offering school systems and policy makers scientifically based evidence aiding them in selecting and developing professional development programs within their schools and school districts. The study used the methodology of meta-analysis. It used statistical methods for combining results from different studies, sources of agreement among those studies and other relationships that may emerge in the context of multiple studies. The following section will describe the process and the results of this meta-analysis.

Data Analysis

Cohen's (d) effect size was used to provide a common scale for comparison of study outcomes. There were seven types of data analysis conducted in this study used to evaluate the impact that professional development intervention programs and its components (duration, content, and intervention) have on K-12 mathematics teachers and students' achievement. The first analysis calculated the individual effect sizes of each intervention found in each study and tested for statistical significance (see Table 4). Next, subgroups were developed by combining individual effect sizes within each study (see Table 5). These analyses lead to an overall effect size across studies. Moreover, each study was evaluated as the unit of analysis calculating one effect size per study (see Table 6). In addition, Table 6 presents the analysis of the combination of individual programs that have similar components (duration, content, and intervention) to produce an overall impact that these characteristics have on students' mathematics achievement. In addition, heterogeneity and significance analyses were conducted (see Tables 7 and 8). This was followed by intervention subgroups analyses evaluating impacts by duration, program content, and intervention components. Lastly, an analysis was performed to investigate the potential of publication bias.

Table 4
Individual Effect Size Analysis

Meta-Analytic results for math scores by intervention type and math scores by program type

Math-focused		Sample Size				95% CI	
	Grade Level	Treatment	Control	Total	ES (d)	Lower	Upper
Allen (2012)	3rd	60	60	120	0.536**	0.172	0.099
Allen (2012)	3rd	60	60	120	0.390*	0.029	0.751
Allen (2012)	3rd	60	60	120	0.718***	0.349	1.087
Broyles (2009)	9th	3	13	16	3.924*	2.073	5.774
Broyles (2009)	9th	8	13	21	0.736	-0.172	1.645
Broyles (2009)	9th	10	23	33	-1.173*	-1.967	-0.378
Broyles (2009)	9th	10	23	33	-0.755	-1.520	0.009
Broyles (2009)	9th	3	3	6	3.959**	1.206	6.712
Broyles (2009)	9th	8	3	11	3.209***	1.323	5.096
Broyles (2009)	9th	10	23	33	-0.847*	-1.617	-0.077
Broyles (2009)	9th	10	23	33	-1.206**	-2.004	-0.409
Broyles (2009)	10th	5	4	9	1.452	-0.024	2.928
Broyles (2009)	10th	7	4	11	1.657*	0.247	3.067
Broyles (2009)	10th	5	7	12	-3.906***	-5.846	-1.968
Broyles (2009)	10th	3	7	10	-2.095*	-3.730	-0.460
Broyles (2009)	10th	5	4	9	1.049	-0.352	2.450
Broyles (2009)	10th	7	4	11	2.203**	0.668	3.738
Broyles (2009)	10th	5	7	12	-1.619*	-2.937	-0.301
Broyles (2009)	10th	3	7	10	-1.457	-2.953	0.039
Dash (2012)	5th	648	790	1438	0.049	-0.055	0.153
DiNardo (2010)	3rd	54		54	0.495**	0.212	0.777
DiNardo (2010)	5th	67		67	0.442**	0.192	0.693
Heller ((2007)	2nd	271	284	555	0.411***	0.242	0.579
Heller ((2007)	4th	306	449	755	0.763***	0.613	0.913
Heller ((2007)	6th	276	279	555	0.353***	0.185	0.520
Heller ((2007)	2nd	119	137	256	-0.243	-0.490	0.003
Heller ((2007)	4th	131	186	317	0.388**	0.162	0.613
Heller ((2007)	6th	124	158	282	-0.293**	-0.530	-0.057
Krupa (2011)	Alg 1	569	1942	2511	0.708***	0.612	0.803
Krupa (2011)	Alg2	290	1612	1902	-0.284***	-0.409	-0.158
Kuchey (2009)	1st	22	96	118	0.457	-0.010	0.924
Kuchey (2009)	1st	22	96	118	0.468*	0.000	0.935
Kuchey (2009)	2nd	44	55	99	-0.212	-0.610	0.185
Kuchey (2009)	2nd	44	55	99	-0.354	-0.754	0.045
Kuchey (2009)	3rd	164	101	265	0.540***	0.288	0.792
Kuchey (2009)	3rd	164	101	265	1.535***	1.254	1.815
McGatha (2009)	6th	98	87	185	-0.498***	-0.791	-0.205
McGatha (2009)	7th	127	96	223	0.445***	0.177	0.713
McGatha (2009)	8th	109	138	247	-0.496***	-0.751	-0.241

Table 4 (continued)

Meta-Analytic results for math scores by intervention type and math scores by program type							
Math-focused		Sample Size				95% CI	
	Grade Level	Treatment	Control	Total	ES (d)	Lower	Upper
O'Dwyer (2010)	5th	648	790	1438	0.130***	0.053	0.207
O'Dwyer (2010)	8th	799	1062	1861	0.117***	0.047	0.186
Phelan (2011)	6th	842	633	1475	0.070	-0.033	0.173
Phelan (2011)	6th	1496	1120	2616	0.306***	0.228	0.384
Polly (2014)	K-5th	629		629	0.0132*	0.000	0.157
Polly (2014)	K-5th	542		542	0.142**	0.027	0.195
Polly (2014)	K-5th	450		450	0.156***	0.063	0.249
Ross (2006)	6th	406	310	716	-0.127	-0.275	0.021
Ross (2006)	6th	408	309	717	-0.038	-0.122	0.174
Ross (2006)	6th	408	309	717	-0.059	-0.190	0.106
Ross (2006)	6th	408	309	717	-0.080	-0.163	0.132
Ross (2006)	6th	406	308	714	-0.101	-0.114	0.183
Ross (2006)	6th	408	309	717	-0.122	-0.078	0.218
Ross (2006)	6th	408	309	717	-0.142	-0.027	0.269
Ross (2006)	6th	407	309	716	-0.163	-0.053	0.243
Santagata (2011)	6th	2559	2564	4823	0.048	-0.007	0.103
Tesele ((2012)	8th	596287	365583	961870	-0.058***	-0.062	0.054
Tesele ((2012)	8th	393017	662465	1055482	-0.083***	-0.087	-0.079
Tesele ((2012)	8th	1501197	167091	1668288	0.067***	0.062	0.072
Tesele ((2012)	8th	946590	269893	1216483	0.049***	0.045	0.054
Tesele ((2012)	8th	898936	260416	1159352	-0.025***	-0.029	-0.021
Tesele ((2012)	8th	570374	536594	1106968	-0.105***	-0.109	-0.102
Tesele ((2012)	8th	482301	798696	1280997	0.065***	0.062	0.069
Tesele ((2012)	8th	507600	478616	986216	-0.096***	-0.100	-0.092
Tesele ((2012)	8th	260479	1184775	1445254	-0.327***	-0.321	-0.323
Tesele ((2012)	8th	1103223	384499	1487722	-0.084***	-0.087	-0.080
Van Haneghan (2009)	2nd	153	41	194	0.117	-0.228	0.462
Van Haneghan (2009)	2nd	153	41	194	0.229	-0.116	0.575
Van Haneghan (2009)	2nd	153	41	194	0.275	-0.071	0.621
Van Haneghan (2009)	2nd	153	41	194	0.207	-0.139	0.552
Van Haneghan (2009)	2nd	153	41	194	0.007	-0.337	0.352
Van Haneghan (2009)	5th	91	26	117	0.370	-0.069	0.808
Van Haneghan (2009)	5th	91	26	117	0.480*	0.040	0.920
Van Haneghan (2009)	5th	91	26	117	0.483*	0.043	0.924
Van Haneghan (2009)	5th	91	26	117	0.730***	0.285	1.176
Van Haneghan (2009)	5th	289	91	380	0.737***	0.496	0.978
Wimberley (2013)	8th	50	50	100	1.322***	0.890	1.755
Totals		7276447	5124549	12400696			

Note. All math scores [16 studies, 76 Effect Sizes (ES)]. Studies with sufficient data to calculate standardized effect sizes for students'achievement outcomes. CI= confidence Interval; ES=effect size; *p≤0.05. **p≤ 0.01. ***p≤0.001

Individual Effect Size Analysis

There were 76 individual effects within 16 studies that had sufficient data to calculate standardized effect sizes for student achievement outcomes (see Table 4). Out of the 76 individual effect sizes (ES) there were 33 statistically significant effects favoring the treatment group (positive ES) and 17 effects that favored the control group (negative ES). There were a total of 50 statistically significant individual effects sizes. All of the studies included in this meta-analysis were focused on mathematical content ranging from 1st grade to 10th grade including algebra 1 and 2. There were six different types of math-focused professional development programs included in this study. The categories are professional learning community (PLC), formative assessment, curriculum, on-line, reform initiated, and large scale study of professional development programs. Within the 16 math-focused programs there were five programs in which all of the effects of those programs were statistically significant and favored the treatment group (11 individual effect sizes).

Subgroups Effect Size Analysis

Table 5

Subgroup Effect Size Analysis

Meta-Analytic results for math scores by program intervention				
Math-focused Interventions			95% CI	
	Grade Level	ES (d)	Lower	Upper
Allen (2012)	3rd	0.546**	0.335	0.756
Broyles (2009)	9th	-0.356*	-0.699	-0.012
Broyles (2009)	10th	-0.123	-0.653	0.407
Dash (2012)	5th	0.049	-0.055	0.153
DiNardo (2010)	3rd	0.495**	0.212	0.777
DiNardo (2010)	5th	0.442**	0.192	0.693
Heller (2007)	2nd	0.203**	0.064	0.342
Heller (2007)	4th	0.648***	0.523	0.773
Heller (2007)	6th	0.136	-0.001	0.273
Krupa (2011)	Alg 1	0.708***	0.612	0.803
Krupa (2011)	Alg2	-0.284***	-0.409	-0.158
Kuchey (2009)	1st	0.463**	0.132	0.793
Kuchey (2009)	2nd	-0.238*	-0.565	-0.001
Kuchey (2009)	3rd	0.985	0.798	1.172
McGatha (2009)	6th	-0.498***	-0.791	-0.205
McGatha (2009)	7th	0.445***	0.177	0.713
McGatha (2009)	8th	-0.496***	-0.751	-0.241
O'Dwyer (2010)	5th	0.130***	0.053	0.207
O'Dwyer (2010)	8th	0.117***	0.047	0.186
Phelan (2011)	6th B	0.07	-0.033	0.173
Phelan (2011)	6th W	0.306***	0.228	0.384
Polly (2014)	K-5th	0.132*	0.000	0.157
Polly (2014)	K-5th	0.142**	0.027	0.195
Polly (2014)	K-5th	0.156***	0.063	0.249
Ross (2006)	6th	0.02	-0.032	0.072
Santagata (2011)	6th	0.048	-0.007	0.103
Tesele ((2012)	8th	-0.061***	-0.063	-0.060
Van Haneghan (2009)	2nd	0.167*	0.012	0.321
Van Haneghan (2009)	5th	0.616	0.453	0.778
Wimberley (2013)	8th	1.322***	0.890	1.755

Math Focused Programs 16 Studies; 30 effect sizes; Note: All Math Scores; CI= confidence Interval; ES=effect size; *p≤0.05. **p≤ 0.01. ***p≤0.001

After combing the 76 individual effects to create subgroups for each study, there were a total of 30 effects sizes that were produced (see Table 5). This would allow the opportunity to observe the effects that the math-focused programs had on each subgroup (independent groups) such as grade levels or course levels based on students' achievement. The results from this analysis reveal that the math intervention programs implemented in Allen (2012), DiNardo (2010), O'Dwyer (2010), Polly (2014), and Wimberley (2013) showed a positive statistically significant effect on student achievement. The teachers' who participated in those programs had a positive impact on students' achievement. For example, when looking at 3^{rd} grade (Allen, 2012) the independent impact estimate for the math intervention program is statistically significant with a pooled effect size of 0.546 ($p \leq 0.01$). This represents a medium pooled estimate showing that the students of teachers participating in the professional development programs achieved an estimated 0.546 standard deviations higher score on math assessments than students whose teachers did not participate in these programs. Whereas, a more meaningful way to examine the effects would be if a student in the comparison group scored in the 50^{th} percentile, an equivalent student whose teacher participated in the professional development would score in the 70^{th} percentile.

DiNardo (2010) study showed that the math intervention program pooled estimate for 3^{rd} grade is 0.495 ($p \leq 0.01$) and 0.442 ($p \leq 0.01$) for 5^{th} grade. Both effect sizes have somewhat of a medium effect. If a student in the comparison group scored in the 50^{th} percentile, an equivalent student whose teacher participated in the program would score in 69^{th} percentile for 3^{rd} grade and 67^{th} percentile for 5^{th} grade. In addition, the O'Dwyer (2010) study showed that the math intervention program pooled estimate for 5^{th} grade is 0.130 ($p \leq 0.001$) and 0.117 ($p \leq 0.001$) for 8^{th} grade. Both of these effect sizes have a small effect. If a student in the comparison group scored in the 50^{th} percentile, an equivalent student whose teacher participated in the program would score in 55^{th} percentile for 5^{rd} grade and 55^{th} percentile for 8^{th} grade. Next, Polly (2014) study implemented three end of the unit assessments for each grade level (K-5). Thus, each round represented the average students' gains (post-pre) score per each end of the unit assessment. The results showed that the math intervention program pooled estimate for K-5^{th} grade during the 1^{st} round is 0.132 ($p \leq 0.05$), 2^{nd} round 0.142 ($p \leq 0.01$), and 3^{rd} round 0.156 ($p \leq 0.001$). These effect sizes have a small effect. If a student in the K-5 comparison group scored in the 50^{th} percentile, an equivalent student whose teacher participated in the program would score in 55^{th} percentile for 1^{st} round, 56^{th} percentile for 2^{nd} round, and 56^{th} percentile for third round. Lastly, Wimberley (2013) study showed that the math intervention program pooled estimate for 8^{th} grade is 1.322 ($p \leq 0.001$). This is a large effect. If a student in the comparison group scored in the 50^{th} percentile, an equivalent student whose teacher participated in the program would score in 91^{st} percentile for 8^{th} grade.

On the other hand, the other 11 studies have some inconsistent results. Some studies show a statistically significant positive effect for one grade meaning that the effects favored the treatment group and another grade may show a statistically significant negative effect. In other words, the control group did better on the assessment than the treatment group. Broyles (2009) study showed that the math intervention program had no effect on students' achievement for the 9^{th} (ES=-0.356, $p \leq 0.05$) or 10th grade (ES=-0.13, ns). Heller (2007) study showed that the math intervention program pooled estimate for 2^{nd} grade is 0.203 ($p \leq 0.01$) and 0.648 ($p \leq 0.001$) for 4^{th} grade. This represents a medium effect for 2^{nd} grade, a large effect for 4^{th} grade, and no significant effect for 6^{th} grade (ES=0.136, ns). If a student in the comparison group scored in the 50^{th} percentile, an equivalent student whose teacher participated in the program for 2^{nd} grade would score in the 58^{th} percentile and 74^{th} percentile for 4^{th} grade. Krupa (2011) study showed that the Algebra 1 math intervention program pooled estimate is 0.708 ($p \leq 0.001$) and that there was a negative effect (no effect) on Algebra 2 (ES=-0.248, $p \leq 0.001$). The control group did better on the Algebra 2 assessment than the treatment group. There is a medium effect for Algebra 1. If a student in the Algebra 1 comparison group scored in the 50th percentile, an equivalent student whose teacher participated in the program would score in the 76th percentile. Kuchey (2009) study showed that the math intervention program pooled estimate for 1st grade is 0.463 ($p \leq 0.01$), -0.238 ($p \leq 0.05$) for 2nd, and no significant effect for 3rd grade (ES=0.985, ns). There is a medium effect for 1st grade, a negative effect on 2nd, and no significant effect on 3rd grade. If a student in the 1st grade comparison group scored in the 50th percentile, an equivalent student whose teacher participated in the program would score in the 68th percentile. McGatha (2009) study showed that the math intervention program pooled estimate for 6th grade is -0.498 ($p \leq 0.001$), 0.445 ($p \leq 0.001$) for 7th grade and -0.496 ($p \leq 0.001$) for 8th. In both 6th grade and 8th grade the control group did significantly better than the treatment group. This study showed that the 7th grade math intervention program has a medium effect on students' achievement. If a student in in the 7th grade comparison group scored in the 50th percentile, an equivalent student whose teacher participated in the program for would score in the 67th percentile. Phelan (2011) study showed that the 6th grade math intervention program had no significant effect on students' achievement between schools (ES=0.070, ns) but showed that there was a small within school effect of 0.306 ($p \leq 0.001$). If a student in the 6th grade within school comparison group scored in the 50th percentile, an equivalent student whose teacher participated in the program would score in the 62nd percentile.

Ross (2006) (ES=0.20, ns) and Santagata (2011) (ES=0.048, ns) are two 6th grade math intervention program studies that have no statistical significant effect on students' achievement. In addition, Tesele (2012) study showed that the math intervention program pooled estimate for 8th grade is - 0.061 ($p \leq 0.001$) meaning that the control group scored statistically significant better on the assessment than the treatment group. The intervention had no effect on students' achievement. Lastly, Van Haneghan (2009) study showed that the math intervention program pooled estimate for 2^{nd} grade is 0.167 ($p \leq 0.05$) and no significant effect was shown for 5^{th} grade (ES=0.616, ns). There is a small effect for 2^{nd} grade. If a student in the comparison group scored in the 50^{th} percentile, an equivalent student whose teacher participated in the program for 2^{nd} grade would score in the 57^{th} percentile.

Single Study Unit Analysis

Table 6

Single Study Unit Analysis

Paper No.	Math Intervention Programs	ES (d)	95% CI Lower	95% CI Upper	Z-Value	Duration	Content	Intervention
66	Allen (2012)	0.511***	0.301	0.721	4.770***	D2	C2	W3
63	Broyles (2009)	-0.450***	-0.699	1.015	-3.547***	D1	C2	W3
50	Dash (2012)	0.049	-0.055	0.153	0.922	D2	C3	W3
81	DiNardo (2010)	0.466***	0.278	0.653	4.864***	D1	C2	W2
36	Heller ((2007)	0.408***	0.332	0.484	10.481***	D1	C3	W3
82	Krupa (2011)	0.385***	0.310	0.46	10.077***	D3	C3	W2
83	Kuchey (2009)	0.014	-0.113	0.140	0.213	D3	C3	W3
18	McGatha (2009)	-0.204**	-0.357	-0.050	-2.599**	D2	C2	W3
4	O'Dwyer (2010)	0.123***	0.071	0.174	4.649***	D1	C3	W3
84	Phelan (2011)	0.218***	0.156	0.280	6.881***	D2	C1	W3
58	Polly (2014)	0.142***	0.093	0.191	5.689***	D2	C3	W3
26	Ross (2006)	0.013	-0.039	0.065	0.485	D1	C3	W3
20	Santagata (2011)	0.048	-0.007	0.103	1.713	D2	C3	W2
34	Tesele ((2012)	-0.057***	-0.058	-0.056	-98.525***	D2	C3	W3
80	Van Haneghan (2009)	0.229***	0.118	0.340	4.033***	D3	C3	W2
68	Wimberley (2013)	1.322***	0.049	0.890	5.990***	D2	C3	W3
	Total Fixed ES 16 Studies	-0.056***	-0.057	-0.055	-97.57***			
	Total Random ES 16 Studies	0.164***	0.070	0.259	3.417***			

Note. Studies with sufficient data to calculate standardized effect sizes for student achievement outcomes. CI=confidence interval; ES=effect size;*p≤0.05. **p≤ 0.01. ***p≤0.001; Duration D1-One time, short term; D2-One academic year; D3-Multiple years; Content C1-Content only; C2-Pedagogy only; C3-Content and pedagogy; Interventions W1-Worskshop only; W2-Worskshop + coaching; W3-Workshop + other

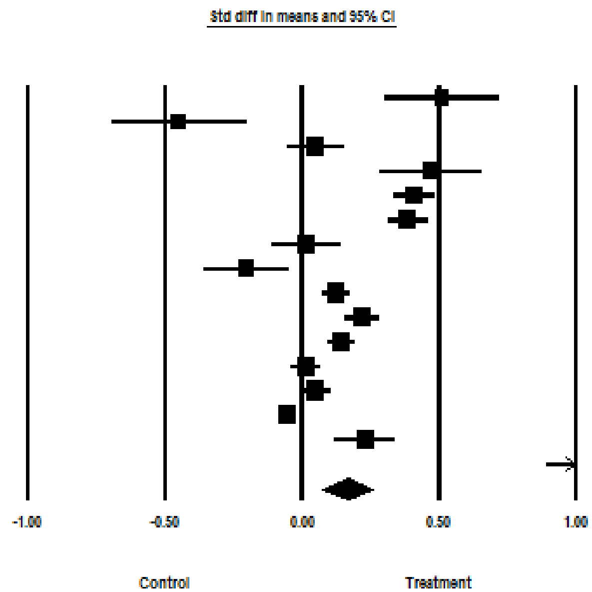
Table 7

Forest Plot

Forest Plot

Model	Study name	Subgroup within study	Std diff in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value	Relative weight	Relative weight	Relative weight	Relative weight
	Allen, 2012_66	Combined	0.511	0.107	0.011	0.301	0.721	4.770	0.000	0.00		5.29	
	Broyles, 2009_63	Combined	-0.450	0.127	0.016	-0.699	-0.202	-3.547	0.000	0.00		4.79	
	Dash, 2012_50	Dash 5th	0.049	0.053	0.003	-0.055	0.153	0.922	0.356	0.01		6.60	
	DiNardo, 2010_81	Combined	0.466	0.096	0.009	0.278	0.653	4.864	0.000	0.00		5.59	
	Heller, 2007_36	Combined	0.408	0.039	0.002	0.332	0.484	10.481	0.000	0.02		6.86	
	Krupa, 2011_82	Combined	0.385	0.038	0.001	0.310	0.460	10.077	0.000	0.02		6.87	
	Kuchey, 2009_83	Combined	0.014	0.064	0.004	-0.113	0.140	0.213	0.832	0.01		6.36	
	McGatha, 2011_18	Combined	-0.204	0.078	0.006	-0.357	-0.050	-2.599	0.009	0.01		6.03	
	O'Dwyer, 2010_4	Combined	0.123	0.026	0.001	0.071	0.174	4.649	0.000	0.05		7.03	
	Phelan, 2011_84	Combined	0.218	0.032	0.001	0.156	0.280	6.881	0.000	0.03		6.96	
	Polly, 2014_58	Combined	0.142	0.025	0.001	0.093	0.191	5.689	0.000	0.05		7.04	
	Ross, 2006_26	Combined	0.013	0.027	0.001	-0.039	0.065	0.485	0.628	0.05		7.02	
	Santagata, 2011_20	Santagata	0.048	0.028	0.001	-0.007	0.103	1.713	0.087	0.04		7.01	
	Tesele, 2012_34	Combined	-0.057	0.001	0.000	-0.058	-0.056	-98.525	0.000	99.69		7.18	
	Van Haneghan, 2009_80	Combined	0.229	0.057	0.003	0.118	0.340	4.033	0.000	0.01		6.53	
	Wimberley, 2013_68	Wimberley 8th	1.322	0.221	0.049	0.890	1.755	5.990	0.000	0.00		2.86	
Random			0.164	0.048	0.002	0.070	0.259	3.417	0.001				

Statistics for each study; Weight (Fixed)



Meta Analysis

A single unit study analysis was conducted which included all 76 individual effects sizes that were combined into 30 independent subgroups (see Tables 4 and 5). The 30 independent effect sizes within 16 studies were further combined to produce a single study unit effect size (see Table 6). The results of the single unit analysis of the 16 single study effect sizes in this meta-analysis suggest evidence of a positive overall program effects on student achievement. This is also represented by the diamond at the bottom of the Forest Plot (see Table 7). There are a total of 12 significant pooled effects out of the 16 individual study effects. Within the math focused intervention nine programs overall effects are statistically significant and favored the treatment group (see Tables 6 and 7). On the other hand, there are three math intervention programs (McGatha_18, Tesele_34, and Broyles_63) that have statistically significant negative pooled estimates (ES=-0.204, p≤0.01), (ES=-0.057, p≤0.001), and (ES=-0.450, p≤0.001) (Tables 6 & 7). In other words, the control group did better than the treatment group. The programs had no impact effect on students' achievement. Lastly, there were four programs (Santagata_20, Ross_26, Dash_50, and Kuchey_83) that were not significant at all (ES=0.048, ns), (ES=0.013, ns), (ES=0.049, ns), and (ES=0.014, ns) (see Table 6). These effects lie on or very close to the line of no effect (overall average mean of 0) on the Forest Plot (see Table 7).

The majority of the single unit study impact estimates for the math professional development programs are statistically significant with a pooled effect size of 0.164 (p≤0.001), 95% CI (0.070, 0.259), and Z=3.417 (p≤0.001) (see Tables 6 and 7). This is a modest pooled estimate showing that the students of teachers participating in the professional development programs achieved an estimated 0.164 standard deviations higher score on math assessments than students whose teachers did not participate in these programs. Whereas, a more meaningful way to examine the effects would be that if a student in the comparison group scored in the 50^{th}

percentile, an equivalent student whose teacher participated in the professional development would score in the 57th percentile.

The positive effect sizes ranged from a low of 0.013 to a high of 1.322. When looking at each study separately, Allen_66 (2012) study showed that the math intervention program pooled estimate is 0.511 ($p \leq 0.001$), 95% CI (0.301, 0.721), $Z=4.770$ ($p \leq 0.001$). This means that professional development has an overall medium effect on student achievement. If a student in the comparison group scored in the 50th percentile, an equivalent student whose teacher participated in the program would score in 70th percentile. DiNardo_83 (2010) study showed that the math intervention program pooled estimate is 0.466 ($p \leq 0.001$), 95% CI (0.278, 0.653), $Z=4.864$ ($p \leq 0.001$) showing an overall medium effect on student achievement. If a student in the comparison group scored in the 50th percentile, an equivalent student whose teacher participated in the program would score in 68th percentile. Heller_36 (2007) study showed that the math intervention program pooled estimate is 0.408 ($p \leq 0.001$), 95% CI (0.332, 0.484), $Z=10.481$ ($p \leq 0.001$) showing an overall medium effect on student achievement. If a student in the comparison group scored in the 50th percentile, an equivalent student whose teacher participated in the program would score in 66th percentile. Krupa_82 (2011) study showed that the math intervention program pooled estimate is 0.385 ($p \leq 0.001$), 95% CI (0.310, 0.460), $Z=10.077$ ($p \leq 0.001$) displaying an overall medium effect on student achievement. If a student in the comparison group scored in the 50th percentile, an equivalent student whose teacher participated in the program would score in 65th percentile. O'Dwyer_4 (2010) study showed that the math intervention program pooled estimate is 0.123 ($p \leq 0.001$), 95% CI (0.071, 0.174), $Z=4.249$ ($p \leq 0.001$) having an overall small effect on student achievement. If a student in the comparison group scored in the 50th percentile, an equivalent student whose teacher participated in the program would score in 55th percentile. Phelan_84 (2010) study showed that the math intervention program pooled estimate is 0.218 ($p \leq 0.001$), 95% CI (0.156, 0.280), Z=6.881 ($p \leq 0.001$) representing an overall small effect on student achievement. If a student in the comparison group scored in the 50th percentile, an equivalent student whose teacher participated in the program would score in 59th percentile. Polly_58 (2010) study showed that the math intervention program pooled estimate is 0.142 ($p \leq 0.001$), 95% CI (0.093, 0.191), Z=5.689 ($p \leq 0.001$) having an overall small impact on student achievement. If a student in the comparison group scored in the 50th percentile, an equivalent student whose teacher participated in the program would score in 56th percentile. Van Haneghan_80 (2009) study showed that the math intervention program pooled estimate is 0.229 ($p \leq 0.001$), 95% CI (0.118, 0.340), Z=4.033 ($p \leq 0.001$) representing an overall small effect on student achievement. If a student in the comparison group scored in the 50th percentile, an equivalent student whose teacher participated in the program would score in 59th percentile. Wimberley_68 (2013) study showed that the math intervention program pooled estimate is 1.322 ($p \leq 0.001$), 95% CI (0.049, 0.890), Z=5.990 ($p \leq 0.001$) displaying an overall small effect on student achievement. If a student in the comparison group scored in the 50th percentile, an equivalent student whose teacher participated in the program would score in 91st percentile.

There are three studies that have a statistically significant negative math intervention program pooled estimates which means that the control group did better on the assessment than the treatment group. Therefore, the intervention had no effect on the treatment group. The first is Broyles_63 (2009) study showing that the math intervention program pooled estimate is -0.450 ($p \leq 0.001$), 95% CI (-0.699, 1.015), Z=-3.547 ($p \leq 0.001$). Next, McGatha_18 (2009) study displayed the math intervention program pooled estimate of -0.204 ($p \leq 0.01$), 95% CI (-0.357, -

0.050), Z=-2.599 (p≤0.01). Lastly, Tesele_34 (2012) study showed the math intervention program pooled estimate of -0.057 (p≤0.001), 95% CI (-0.057, -0.056), Z=-98.525 (p≤0.001).

The next four studies Dash_50 (2012), Kuchey_83 (2009), Ross_26 (2006), and Santagata_20 (2011) math intervention programs did not have a statistically significant impact on students' achievement. These math intervention programs had no effect on student gains.

Significance and Heterogeneity Analysis

Table 8
Significance and Heterogeneity Analysis

Model			Test of null (2-Tail)		Heterogeneity		Tau Squared		
Model	Number Studies	Point estimate	Z-value	P-value	Q-value	P-value	Tau Squared	Variance	Tau
Fixed	16	-0.056	-97.571	0.000	621.733	0.001	0.032	0.001	0.180
Random	16	0.164	3.417	0.001					

The overall fixed point estimate effect size for all 16 studies is -0.056 (p≤0.001). The question is, can we reject the null hypothesis that the true effect size is zero? The results showed that Z=-97.571 (p≤0.001), and Q=621.733 (p≤0.001), df=15 (see Table 8).

The Q statistics is based on how much evidence, how many studies, and how much dispersion there is between one point estimate to the next and how precise the estimates are (Shaneyfelt, 2013). The confidence intervals of these 16 studies are narrow which offers a more precise estimate and a significant p-value (see Table 7). Thus Q=621.733, (p=.000), this states that if the population of all of these studies are the same, then 0 cases out of 100 meta-analyses of this sort would be expected to see this type of dispersion. Therefore the null hypothesis is to reject that the dispersion simply represents sampling errors. In other words, the true effects of these studies are not identical. This is evidence that the true effect varies from one study to the next. I-squared statistics showed 97.59 (98%) of the dispersion; thus, the effect sizes are probably due to real dispersion of the true effect sizes and not simply due to random dispersions (see Table 8). I-squared statistics can range from 0% to 100%. Tau-squared statistics displayed evidence that there is 0.032 between studies' variance. The true effect varies from the true mean; such that each study represents a different population. Since the evidence supports the fact that the dispersion of true effects varies and is not due to sampling errors; and that the true effect varies between studies, the null hypothesis is rejected that the true effects are the same for all studies. Tau which is the standard deviation of the true effect study effect is 0.180 (see Table 8). Subsequently, the results of this meta-analysis show that there is statistical significant heterogeneity. This means that there is evidence that the difference between these studies is not due to chance. Thus, the random effects model was used in this meta-analysis to calculate single unit study analysis. In addition, the random effect model is not affected by extreme weight (sample size) of any study.

Table 9

Impacts by duration, program content, and intervention components

Math Interventions

		N	Impact	Studies Number	Total ES for each study
Math Impacts		30(16)	0.164***		
Duration					
D1	One time, short term	10(5)	0.131	4,26, 36, 63, 81	2,1,3,2,2=10
D2	One academic year	13(8)	**0.068****	18,20,34,50,58,66,68,84	3,1,1,1,3,1,1,2 =13
D3	Multiple years	**7(3)**	**0.214***	80,82,83	2,2,3=7
Content					
C1	Content only	2(1)	**0.218*****	84	2
C2	Pedagogy only	8(4)	0.083	18,63,66,81	3,2,1,2=8
C3	Content and pedagogy	**20(11)**	**0.075*****	4,20,26,34,36,50,58,68,80,82,83	2,1,1,1,3,1,3,1,2,2,3=20
Intervention					
W1	Workshop only	0(0)			
W2	Workshop + coaching	**7(4)**	**0.096*****	20,80,81,82	1,2,2,2=7
W3	Workshop + other	23(12)	**0.102****	4,18,26,34,36,50,58,63,66,68,83,84	2,3,1,1,3,1,3,2,1,1,3,2=23

Note. This table includes studies that has sufficient data to calculate standardized means effect sizes for student achievement outcomes. The cases in the table where a statistically significant difference across subcategories ($p<0.05$) are presented in bold.
N includes the total number of effect sizes with the number of studies in parentheses. *p≤0.05. **p≤ 0.01. ***p≤0.001

Intervention Components Subgroup Analysis

Intervention Duration

To understand the different components of PD programs fully, studies were grouped by duration, content focus, and delivery format. The goal of this analysis by these categories was to examine the impact of these components on the success of the PD programs.

All of the math intervention programs in this study were implemented as short term (D1), one academic year (D2), or over multiple years (D3). There were five math intervention programs (Allen_4, Ross_26, Heller_36, Broyles_63, and DiNardo_81) that occurred one time or over a short period of time. Table 9 shows that these studies had no significant effect on student achievement (ES=0.131, ns). These results are a testament to the current findings in research that one-stop or short term professional development opportunities are not effective for teachers' learning and do not promote students' gains (Garet el al., 2001; Cooper, 2004). In addition, there were eight (McGatha_18, Santagata_20, Tesele_34, Dash_50, Polly_58, Allen_66, Wimberley_68, and Phelan_84) math intervention programs that occurred for one academic year which had a small but significant effect on student achievement (ES=0.068, $p \leq 0.01$). If a student in the comparison group scored in the 50^{th} percentile, an equivalent student whose teacher participated in a professional development program for a duration of one academic year would score in 53^{th} percentile. Whereas, the largest impact on student achievement was evident with the 3 math intervention programs (Van Haneghan_80, Krupa_82, Kuchey_83) that were conducted over multiple years (ES=0.214, $p \leq 0.05$). If a student in the comparison group scored in the 50^{th} percentile, an equivalent student whose teacher participated in a professional development program with duration of multiple years would score in 58^{th} percentile. These findings are supported in literature showing that increasing student achievement is positively related to teachers' experiencing a longer duration of professional development opportunities (Blank, 2013; Hill, 2007).

Intervention Focus

In mathematics professional development programs the intervention focus is normally concentrated in the areas of substantive content, pedagogy only, or content and pedagogy. When content and pedagogy are incorporated together the intervention often promotes the underlying principles of pedagogical content knowledge (how to teach mathematics) and the focus is both on knowing mathematics and knowing how to teach that content. Table 8 shows that there is only one math intervention program that is focused on content only (Phelan_84). This program has a larger effect on student achievement (ES=0.218, $p \leq 0.001$) than content and pedagogy programs (O'Dwyer_4, Santagata_20, Ross_26, Tesele_34, Dash_50, Polly_58, Wimberley_68, Van Haneghan_80, Krupa_82, and Kuchey_83) (ES=0.075, $p \leq 0.001$). If a student in the comparison group scored in the 50^{th} percentile, an equivalent student whose teacher participated in a content only professional development program would score in 59^{th} percentile, and 53^{rd} percentile for content and pedagogy program. This is contrary to Hill et al. (2005) study showing that teachers' mathematical knowledge as well as their pedagogical knowledge together has a greater effect on students' achievement than teachers' content knowledge alone. In support of the content focused programs having the largest effect, a review of 57 studies found that there is a positive relationship between teachers' subject matter knowledge and higher student achievement (Wilson et al., 2002). However, pedagogy only intervention programs (McGatha_18, Broyles_63, Allen_66, and DiNardo_81) had no effect on students' achievement (ES=0.075, ns). Research literature states that in order for teachers' to be able to enact the mathematical instructions promoting students' learning, they must have strong content knowledge beyond the concepts and procedures (Kilpatrick et al., 2001).

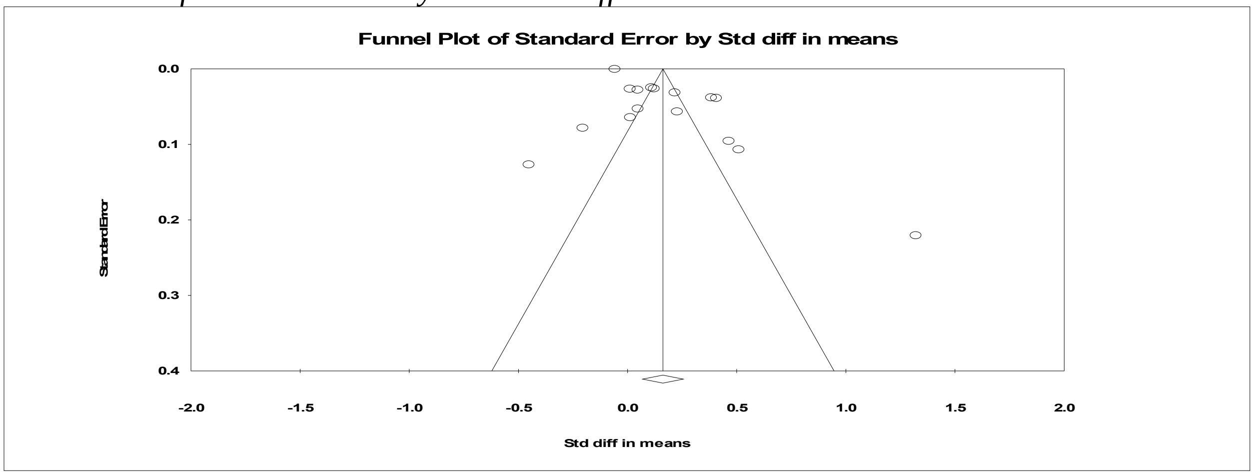
Hill (2007) noted that professional development for teachers can be composed of a variety of delivery formats. The majority of programs contain a focused workshop. In addition to workshops, there are other professional development delivery modes such as coaching, teacher study groups, partnerships, online learning, conferences, fieldwork, and teacher networking (Hill, 2005; Scher et al., 2009). There were no workshop only focused programs in this study. All included math intervention programs were composed of a focused workshop and coaching; or workshop and component(s) other than coaching. There were four math intervention programs (Santagata_20, Van Haneghan_80, DiNardo_81, and Krupa_82) that consisted of workshop and coaching components displaying a small statistically significant effect on student achievement (ES=0.096, $p \leq 0.001$). In addition, 12 math intervention programs (O'Dwyer_4, McGatha_18, Ross_26, Tesele_34, Heller_36, Dash_50, Polly_58, Broyles_63, Allen_66, Wimberley_68, Kuchey_83, and Phelan_84) offered workshop plus additional components other than coaching. These had the largest effect on students' achievement (ES=0.102, $p \leq 0.01$). Professional development math programs offering workshop and coaching resulted in students ranking in the 53.8th percentile whereas workshop plus other was 54.1th in comparison to the control group scoring in the 50th percentile. There is not much difference in the effect of workshop plus coaching and workshop plus other components. These results support research findings that professional development opportunities should not be a one-stop shop but it should be sustained and focused to have a positive effect on students' learning and use many modalities for offering the professional development (Garet el al., 2001; Yoon et al., 2007).

Publication Bias Analysis

Funnel Plot

Graph 1

Funnel Plot of Standard Error by Standard Difference in Means



Every attempt has been made in this meta-analysis to find published and unpublished studies on the impact of professional development programs for K-12 mathematics teachers and students' achievement in an effort to decrease the possibility of publication bias. This is important due to the fact that "studies finding null (absence of statistically significant effect) or negative (statistically effect in the opposite direction expected) are less likely to be published than studies finding positive effects (statistically significant effects in expected directions)" (Card, 2009, p. 257). There were several measures taken to examine the potential of publication bias. First, a funnel plot which included the standardized difference in means (x-axis) and standard error (y axis). The funnel plot displayed reasonable evidence that there is no publication bias in the collection of studies. The studies are distributed symmetrically (balanced) on either side of the average random effect size. When bias is present, the distribution of the studies would not be symmetrical. There would be a higher concentration of studies on one side of the average random effect size (see Graph 1).

Classic Fail-Safe N

Table 10

Classic fail-safe N

Z-value for observed studies	-10.97644
P-value for observed studies	0.00000
Alpha	0.05000
Tails	2.00000
Z for alpha	1.95996
Number of observed studies	16.00000
Number of missing studies that would bring p-value to > alpha	486.00000

Second, a classic fail-safe analysis and Orwin's adaptation was used to evaluate the robustness of the meta-analytic findings. Classic failsafe examines the number of excluded studies that would have to exist for their inclusion in this meta-analysis to lower the average effect size to a non-significant level (Card, 2009). In this case, the Z value for the observed studies is -10.97644. It is highly statistically significant (0.000). The alpha has been set at 0.05. It would take 486 (null) studies all averaging an effect size of zero to exist for their inclusion in this meta-analysis in order for the combined 2-tailed p-value to exceed 0.050. Thus, it shows absence of publication bias in the current study.

In support of the robustness of this meta-analysis, the file drawer problem must be addressed meaning that the number of non-significant missing studies that are presumed to be located in a file drawer, if found and included in this study would nullify the observed effect (Biostat, 2005-2015). The question is how large should fail-safe N be before you conclude that results are robust? According to Rosenthal's (1979) an adequately high fail-safe N tolerance level to the file drawer problem equals 5K + 10; (k is the number of studies). In this meta-analysis there are 16 studies (k). Fail-Safe N should be larger than 90 [5(16) + 10 =90] before the results of this study are considered robust. Since 486 studies are unlikely to be missing from this analysis, the results would be considered stable and robust.

Orwin's Fail-Safe N

Table 11

Orwin's fail-safe N

Std diff in means in observed studies	-0.05628
Criterion for a "trivial" std diff in means	-0.01000
Mean std diff in means in missing studies	0.00000
Number missing studies needed to bring std diff in means over -0.01	75.00000
criterion must fall between other values	

Another approach that evaluates the effect size Fail-Safe N was developed by Orwin (1983). A meaningful criterion value (ES) is selected that falls between 0 and -0.056. The value is denoted as the criterion for a trivial standardized mean difference, -0.01 was chosen. The question that is addressed in this approach is how many missing studies must be added to this analysis in order to bring the point estimate above the threshold of -0.01. 75 more studies with standardized means difference with an average of 0 (no effect), if included in this analysis would shift the effect size towards the null representing a non-statistically significant result (Biostat, 2014). These findings add more evidence that this study is robust to the file drawer problem. Both analyses were conducted using Comprehensive Meta-Analysis, and they indicate the robustness of the collection of studies (Biostat, 2014).

Chapter Summary

This chapter displays the results of the impact of professional development intervention programs and its components (duration, content, and intervention format) for K-12 mathematics teachers and students' achievement spanning from 2003-2013. There were seven types of data analysis conducted in this study: a)analyses of the individual effect sizes of each effect found in each study and tested for statistical significance; b) subgroups analyses-combination of individual effect sizes within each study; c) unit of analysis calculating one effect size per study; d) analyses of the combination of individual programs that have similar components (duration, content, and intervention) to produce an overall impact that these characteristics have on students' mathematics achievement; e) analyses of heterogeneity and significance analyses; f) evaluating impacts according to duration, program content, and intervention format; and g) analyses investigating the potential of publication bias.

Chapter 5: Discussion

Review of Findings

With teacher effectiveness being in the forefront of students' learning and achievement, there is a need for the continued study of the effects of professional development on students' achievement. There are many studies that evaluate the effects of PD on teachers, using teacher reports of changes in their knowledge and teaching practices. But there are few studies that link the PD to students' achievement. For the past two decades there have been many studies that have examined professional development for teachers. However, empirical evidence on the effects that professional development programs, its components, and delivery modality of programs have on students' achievement has been one of the main missing dimensions of many previous studies. This study attempted to fill the gap in literature by offering empirical evidence in regards to the impact of K-12 professional development programs for K-12 mathematics teachers on students' achievement by answering the following questions: 1) What is the average impact of rigorously evaluated recent professional development programs on students' math achievement? 2) Among these rigorously evaluated programs, how do these effects vary? Do programs that incorporate the characteristics that have been asserted through theory and practice to be particularly beneficial to professional development programs have stronger effects than programs that do not?

Overall Effect of Professional Development

In accordance with the first question, this analysis revealed that the pooled effect estimate is a modest but statistically significant effect of 0.164 ($p \leq 0.001$) of rigorously evaluated math focused professional development programs on students' achievement. This effect size showed that students of teachers participating in the professional development programs achieved an estimated 0.164 standard deviations higher score on math assessments than students whose teachers did not participate in these programs. For example, if a student in the comparison group scored in the 50th percentile, an equivalent student whose teacher participated in these professional development programs would score in the 56th percentile. The results of this study showed that the average impact of rigorously evaluated recent professional development programs on math students' achievement is 0.164 ($p \leq 0.001$).

Besides the numerical estimates of the impact of PD and their interpretation in terms of effect sizes, a descriptive as well as statistical approach is also undertaken to highlight the program ingredients that provide the basis for practical implications in the design of PD programs. For the purpose of deeper understanding, the current study further focused on those programs components that have been found to be effective in PD literature. The 16 mathematics professional development programs that were included in this study were grouped into six categories based on the type of program that was administered in each study (See Appendix H). The categories are listed as: a) Professional Learning Communities (PLC); b) Formative Assessment; c) Curriculum Focused; d) On-Line; e) Reform Initiated Professional Development Programs; and f) Large Scale Study of Professional Development Programs. This would allow the opportunity to examine the similarities and differences in each of these studies. Thus, aiding in making comparisons of the impact that the math focused professional development programs may have on students achievement based on duration, content, and interventions modality (see Appendix I). These components of the PD programs are discussed below.

Professional Learning Community (PLC)

Building professional learning communities has been cited as one of the effective ways to promote teachers' learning and professional development. These types of programs offer teachers the opportunity to learn, work together, and share ideas on how to improve students' achievement. The goal of PLC professional development is to help teachers become better teachers and to improve students learning. The 4 professional learning community (PLC) professional development programs in this study are Ross (2006)_26 (ES=0.103, ns), Allen (2012)_66 (ES=0.511, $p \leq 0.001$), Wimberley (2013)_68 (ES=1.322, $p \leq 0.001$), and DiNardo (2010)_81 (ES=0.466, $p \leq 0.001$). The results of three of the programs had a medium to large statistically significant impact on the treatment group but Ross_26 had no effect. The programs that were implemented for one academic year had the largest impact Allen_66, Wimberley _68, followed by DiNardo_81.

All PLC programs' content was focused on pedagogy only except Ross (2006)_26 which focused on content and pedagogy. Even though Ross (2006)_26 (12 hours) and DiNardo (2010)_81 (6 hours) professional development programs were implemented within a short duration they had contradictory results with one having a statistically significant positive impact on students achievement and the other had a negative impact (no impact). Although it is hard to know the reasons for these inconsistent results, one can speculate that the difference could be due to the content differences in the intervention. Since Ross_26 program focused on both content and pedagogy, the effect of this program could have been diminished due to the lack of time allotted in the program to enhance both teachers' content knowledge as well as pedagogical skills whereas DiNardo_81 only focused on pedagogical knowledge. With research supporting (e.g., Hill, 2007; Yoon et al., 2007) the fact that short duration programs have little to no effect on teachers' learning, it is no surprise that trying to incorporate content knowledge and pedagogical knowledge together within a short time frame may not be effective in increasing teachers' learning leading to students' gains. The length of a professional development program is considered one of the key predictors of teachers' learning (Hill, 2007). The more time a teacher has to learn, the more learning can take place. It was also noticed that three programs offered workshop plus some other form of support except DiNardo_81 which offered workshop plus coaching. The overall results support that building learning communities for teachers via PD programs may be an efficacious way to enhance teachers' content knowledge and pedagogical skills. Developing and nurturing professional learning communities seems to hold considerable promise for improving teachers' effectiveness (Vescio, Ross, & Adams, 2007).

Formative Assessment

Formative assessment as part of the professional development has been cited as one way of bringing about desired changes in teachers' instructional practices and classroom management (Dunn, Morgan, O'Reilly, & Parry, 2003). Formative assessment as part of the professional development program has a two-fold purpose. It can be used to offer teachers feedback on the effectiveness of their teaching strategies, promoting adjustments to their instructional strategies to improve students' learning. Secondly it can be used to assist students' learning in the classroom by identifying the areas in which they need to devote more time and effort to improve their understanding (Phelan et al., 2011). These types of programs offer teachers the opportunity to continuously gather information either about their teaching strategies or about what students know and allow them to plan and implement instructional activities accordingly. There were two formative assessment professional development programs in this study in which the analyses of their impact on students' achievement showed contradictory results. McGatha (2009)_18 (ES=-0.204, $p \leq 0.01$) professional development program favored the control group. The students of the control group did better on their math assessment than the treatment group. Whereas, Phelan (2011)_84 (ES=0.218, $p \leq 0.001$) program showed a small statistically significant positive impact on the treatment group. If a student in the comparison group scored in the 50th percentile, an equivalent student whose teacher participated in Phelan_84 formative assessment program would score in the 59th percentile. Both programs were implemented for one academic year, and included workshop and other formats in their program intervention. The content interventions of these studies were different: McGatha_18 focused on pedagogy only and Phelan_84 focused on content only. The results showed that the content only program Phelan_84 had a statistically significant positive effect on students' achievement. Whereas, McGatha_18 the pedagogy only program had a negative effect on students' achievement. In cases when a mathematics professional development program only offers pedagogical strategies, the problem of not improving students' achievement could be due to teachers' need for stronger content knowledge. Teachers with little content knowledge teaching mathematics can have a negative effect on students' achievement (Desimone, 2006). No amount of pedagogical strategies can make up for lack of math content knowledge. Teachers must understand the content of mathematics themselves before assisting their students with their own understanding. Although there is a constant debate about what kind of content knowledge is needed for math teachers to be most effective in contributing to students' gains. It is a general consensus among the experts that teachers' knowledge is critical (Scher & O'Rielly, 2009). There were two other noticeable differences between these two studies. The first is the different ranges of sample sizes (185 to 247) for McGatha_18 and (1475 to 2616) for Phelan_84. Second, the research designs of these two studies were different. McGatha_18 used an experimental design which included 6th, 7th and 8th grade math scores. In addition, Phelan_84 used mixed methods experimental design which incorporated 6th grade within and between school random assignment models along with qualitative data gathered from teacher interviews and observations. These differences in samples and study designs could account for difference in outcome. In spite of the inconsistent results, formative assessment can be a useful approach to professional development.

Curriculum Focused Professional Development

In an effort to increase teacher effectiveness based on high standards for teaching and learning, curriculum-based professional development has been used. This type of professional development focuses on the mathematics curriculum teachers use in their classrooms. Thus, the same curriculum materials are used in teachers' PD program to deepen their understanding of the math content that they teach to their students (Patel et al., 2012). In addition, curriculum-focused professional development allows teachers the opportunity to learn mathematics content knowledge and sometimes pedagogical content knowledge. Moreover, this type of PD provides support and knowledge for following a particular math curriculum. These are the results of the four different curriculum professional development programs that were included in this study: Heller (2007)_36 (ES=0.408, $p \leq 0.001$), Polly (2014)_66 (ES=0.218, $p \leq 0.001$), Broyles (2008)_63 (ES= -0.450, $p \leq 0.001$), and Krupa (2011)_82 (ES=0.385, $p \leq 0.001$). Three of the programs had a small statistically significant impact on the treatment group but Broyles_63 study had a negative effect (no effect). When school districts use curriculum-based professional development it offers teachers an opportunity to link their learning to their real work, promoting changes in instructional practices and increasing subject matter knowledge. These types of professional development opportunities that connect curriculum material and district and state academic standards have been shown to produce effective teaching along with improved student achievement (AERA, 2005). The durations of these programs did not seem to have an effect on the results. For example, Heller_36 (10 hours) was implemented for a short duration, Polly_66 for 1 academic year, Broyles_63 (5 days) for short duration, and Krupa_82 for multiple years.

The content focus for three of the programs Heller_36, Polly_66, and Krupa_82 consisted of content and pedagogy whereas Broyles_63 was pedagogy only. When a mathematics professional development program only offers pedagogical strategies, the problem of not improving students' achievement could be due to teachers' need for stronger content knowledge. Teachers must understand and master the content of mathematics themselves before they can effectively teach it to their students. Overall, these results suggest that curriculum focused PD is likely to have positive impact on student achievement by increasing teachers' capacity to teach the math curriculum.

On-Line Professional Development

On-Line professional development programs are becoming more common. On-line PD programs are used frequently due to the ease of delivery plus easy access by teachers. Teachers can review the on-line material many times at their own convenience. The on-line professional development learning opportunities for teachers in this study were implemented as on-line math courses that focused on teachers' knowledge and instructional practices. Three on-line math focused professional development programs in this study were O'Dwyer (2010)_4 (ES=0.123, $p \leq 0.001$), Santagata (2011)_20 (ES=0.048, ns), and Dash (2012)_50 (ES=-0.049, ns). O'Dwyer_4 was the only online professional development program that had a small statistically significant impact on the treatment group. On the other hand, the other two programs (Santagata_20 and Dash_50) had no effect on the treatment group. The durations of these programs did not seem to have an effect on the results of these programs either. O'Dwyer (2010)_4 was implemented for a short duration (7 weeks), Santagata_20 and Dash_50 spanned for one academic year. All three programs content focus consisted of content and pedagogy. It was also noticed that two programs offered workshop plus some other forms of support except

Santagata_20 which offered workshop plus coaching. The online math focused programs were all conducted using experimental design and had ample sample sizes. Although some studies (O'Dwyer et al., 2010; Russell et al., 2009a; Russell et al., 2009b; Sherin et al., 2009), have shown positive effects of on-line PD programs, this study did not find support in favor of two of the on-line programs. One reason can be that studies demonstrating positive impacts of on-line programs were self-reported positive changes in teaching practice but did not relate the teacher changes to student achievement. Very few studies have looked at student outcomes based on on-line professional development programs.

Reform Initiated Professional Development Program

There were two reform initiative based professional development programs in this study. One of the programs was titled the Maysville Mathematics initiative (MMI) program for a Maryland school district (high poverty district) (Kuchey, 2009_83). The other program was the Initiative for Catholic Schools (ICS) program (Van Haneghan, 2004_80). Both programs were designed to improve teaching strategies and content knowledge leading to students' gains.

The analyses of these programs showed contradictory results. The Van Haneghan (2009)_80 (ES=0.229, $p \leq 0.001$) math-focused program favored the treatment group. This program had a small impact on students' achievement. Whereas, Kuchey (2009)_83 (ES=0.014, ns) had no effect. Both programs were implemented over multiple years and focused on content and pedagogy. The durations and content focus of these programs did not seem to have an effect on students' achievement. Van Haneghan's_80 program intervention components included workshop plus coaching. On the other hand, the Kuchey_83 program consisted of workshop and other forms of support. There is a possibility that the difference in effects of the two programs was due to the coaching component. Research has shown that coaching over time can have a positive effect on elementary student achievement when it is focused on mathematics content, pedagogy and curriculum in elementary schools (Campbell, 2011). Both studies are focused on professional development for elementary teachers and are quasi experimental design studies. Van Hangehan's_80 study consisted of 2nd and 5th grade students. In addition, Kuchey's_83 studies included 1st, 2nd, and 3rd grade students.

Another possible reason for the contradictory results of the impact of these reform-based programs could be elementary teachers' lack of content knowledge that is needed to teach mathematical concepts to young children. Often K-5 teachers are more comfortable teaching language arts as opposed to mathematics. Research has also shown that there have been many professional development programs for elementary teachers that were superficial in nature offering fragmented explanations and disconnected activities covering important topics (Hill, 2007). The professional development programs need to be aligned with content focus, offering deep connected explanations and strategies for understanding math concepts. Despite contradictory findings of the current study, the PD programs in response to reform initiatives may have value in improving teachers' knowledge and skills.

Large Scale Study of Professional Development Programs

Teseles (2012)_34 consisted of a large scale study conducted by the National Center of Educational Statistics (NCES). This study examined the impact that 10 different types of professional development have on students' achievement: a) How students' learn; b) Mathematics theory or application; c) Content standards in mathematics; d) Curriculum materials available in mathematics (units, texts); e) Instructional methods for teaching mathematics; f) Effective use of manipulatives in mathematics Instruction; g) Effective use of calculators in mathematics instruction; h) Methods for assessing students in mathematics; i)Strategies for teaching mathematics to students from diverse backgrounds (including English language learners; j) Preparation of students for district and state tests. This study is unique in its breadth and depth and thus, is discussed separately here.

The analysis of the middle school mathematics professional development results from the National Center of Educational Statistics (NCES) study showed that Teseles (2012)_34 ($ES=-0.057$, $p \leq 0.001$) favored the control group based on the overall average effects of 10 different types of professional developments. The control group students did better on the math assessment than the treatment group. This program had an extremely large sample size ranging from (961,870 to 1,668,288). This result is counter intuitive and does not support the efficacy of PD programs in general. Since so many different types of PD were included in this study, it is hard to speculate the reasons for the overall nil effect.

In sum, these studies show some inconsistencies in the results, sometimes favoring one approach over another and sometimes the reverse. Due to these differences in outcomes, the following discussion addresses the differences and variations in the study interventions and their effects. The primary reason for variation in the effects of these studies was addressed earlier in Table 8, showing the results of Q statistics, meaning the true effects of these studies vary due to population differences.

Variations in Effects of Professional Development Programs

The first part of the second research question is addressed in Tables 8, which examined whether these rigorously evaluated programs effects vary? The results of the Q statistics ($Q=621.733$, $p \leq 0.001$) showed that the true effect varies from the true mean; such that each study represents a different population. The null hypothesis was rejected, stating that the true effects are the same for all studies.

It was found that nine math-focused professional development programs had a statistically significant positive impact on students' achievement: Allen_66, Wimberley_68 and DiNardo_81 which are professional learning community professional developments; Phelan_84 is a formative assessment professional development; Heller_36, Polly_58, and Krupa _82 are curriculum focused professional developments; O'Dwyer_4 is an on-line professional development; and Van Haneghan_80 is a reform initiated math-focused professional development. These programs fall into five different categories, and are quite different from each other, and their effects also vary. These findings suggest that each program's effect on students' achievement had little to do with the type of professional development program. This supports the findings of the National Staff Development Council (2001), which argued that "the most effective professional development comes not from the implementation of a particular set of "best practices", but from the careful adaptation of varied practices to specific content, process, and context elements" (Guskey et al. 2009, p. 497). The National Center of Educational Statistics (NCES) professional development program Teseles_34 listed under the large scale study professional category had no statistically significant impact on students' achievement. On the other hand, there were three programs (Broyles_63, McGatha_18, and Tesele_34) that had a statistically significant negative impact meaning that the program had no effect on the treatment group but favored the control group. The students in the control group did better on the math assessment than the treatment group. Lastly there were 4 programs: Dash_50, Kuchey_83, Ross_26, and Santagata_20 that had no significant effect on students' mathematics achievement.

After reviewing the six different types of professional development programs there were only two categories that had more than one program that had a statistically significant effect on student achievement. The two categories were the professional learning community (PLC) and the curriculum-focused professional developments. PLC professional development programs had the largest statistically significant impact (ES ranged from 0.466 to 1.322) on students' achievement. The duration interventions varied from short term to one academic year (D1 to D2); content intervention ranged from pedagogy only to content and pedagogy (C2 to C3); and the intervention focus ranged from workshop plus coaching to workshop plus other support (W2 to W3). In addition, the curriculum-focused professional development programs that had a statistically significant impact on students' achievement had effect sizes ranging from 0.142 to 0.408. The duration interventions varied from short term to multiple years (D1 to D3); content interventions for all studies included content and pedagogy (C3); and the intervention focus ranged from workshop plus coaching to workshop plus other support other than coaching (W2 to W3) (see Appendix I). Overall, the study supported large variations in the program effects on student learning.

Congruence between PD Literature and the Reviewed Studies

To examine the congruence between PD literature and findings of the current studies' similarities and differences of the pooled estimates of similar program characteristics (duration, content, and intervention) between the 16 mathematics professional development programs are discussed below.

Intervention Duration

Table 9 showed that programs that spanned over multiple years had the greatest impact on students achievement ($ES=0.214$, $p\leq0.05$) followed by programs spanning for one academic year ($ES=0.068$, $p\leq0.01$). In other words, if a student in the comparison group scored in the 50th percentile, an equivalent student whose teacher participated in the professional development would score in the 58th percentile for a multiple year program and 53rd percentile for a one academic year program. On the other hand, programs that were implemented one time or over a short period of time had no effect on students' achievement (ES=0.131, ns). These results support that the length of a professional development program is one of the key elements for improving teaching or learning. The longer the duration of the program the more time teachers have to increase their content knowledge, pedagogical knowledge or both in a professional setting. Short workshops have been found to have little to no effect on teaching and learning (Hill, 2007). Another study (Yoon, et al., 2007) found that when teachers received an average of 49 hours of professional development, their students' achievement increased by 21 percentile points. It was also found that studies that offered more than 14 hours of professional development had a statistically significant positive impact on students' achievement. On the other hand, there was no increase in students' achievement when teachers received between 5-14 hours of professional development (Guskey et al., 2009). The current findings of this study, along with previous research results show that the sufficient duration of mathematics-focused professional development programs is essential in promoting teaching skills that are likely to lead to student achievement.

Intervention Focus

When looking at the impact of intervention focus, the results showed that content focused math programs had a more pronounced effect on student achievement (ES=0.218, $p \leq 0.01$) than content and pedagogy (ES=0.075, $p \leq 0.001$). Content knowledge is the knowledge that teachers need to teach the subject matter to their students (Hill et al., 2005). On the other hand, pedagogical knowledge entails teachers knowing how to teach their students' and how they learn (Killion, 2002). These findings confirm the earlier research that has shown that there is a positive relationship between teachers' content knowledge and higher student achievement

(Wilson et al., 2002). Thus, teachers' content knowledge is essential in improving students' learning (Desimone, 2006). Therefore, the value of teachers' content knowledge and its relationship to students' learning cannot be underestimated. To be an effective teacher, one has to have a deep understanding of the mathematical concepts one teaches. Although the theoretical PD literature supports that PD programs should address content and pedagogy, the results of the present study favored content only programs. In this sense, the results are contrary to Hill's (2005) findings that "student achievement was greater when mathematics teachers have both content knowledge and pedagogical content knowledge" (Patel et al., 2012 p.300). In support of Hill (2005) findings, all experts in the field agree that mathematical content knowledge is important but knowing the mathematics does not ensure that one can teach it to someone else. Therefore, teachers having a deep understanding of mathematical concepts (content knowledge) along with the needed knowledge to teach the mathematics (pedagogical knowledge) are more important than either of these alone for increasing students' achievement (Hill et al., 2005). Thus, the overall impact of pedagogy only programs in this study had no effect on students' achievement (ES=0.083, ns). The results of this study support previous literature on PD that content-focused professional development is an effective way to increase teachers' mathematical knowledge. Teachers having strong content knowledge are essential for students' achievement in mathematics (Desimone, 2006).

One reason for this inconsistency (content only PD program more effective compared to content and pedagogy PD program) is that many teachers may not have sufficient knowledge of mathematics, especially at elementary level. Due to the dearth of math teachers, sometimes teachers teach out of subject area expertise. In such cases PD that focuses on content only may be more useful. Furthermore, in a few studies the treatment did not have an effect or the control group did better than the treatment group. In absence of full information on the selection of teachers in the programs, one can only speculate about the reasons for such counter intuitive results. One possible reason can be non-equivalent treatment and control groups. For example, it is possible that less experienced or less effective teachers volunteered or were persuaded to participate in professional development; in such cases, the student outcomes (achievement scores or grades) may still be higher for control group of teachers because they may be more experienced, better prepared and have more knowledge.

Program Delivery Components

Professional development literature has also supported a variety of modalities for delivering of PD. In general, professional development is delivered via workshops, coaching, courses, on-line and in other ways. In this study, workshop plus other support strategies had a larger impact (ES=0.102, p≤0.01) than workshop plus coaching (ES=0.096, p≤0.001). On the other hand, there were no studies in this meta-analysis that consisted of workshop only. If a student in the comparison group scored in the 50th percentile, an equivalent student whose teacher participated in the professional development would score in the 55th percentile for math focused program which include workshop plus other and 54th percentile for a program that included workshop plus coaching. There is not much difference in the results of the effect of workshop plus coaching or workshop plus other strategies on students' achievement. This could represent the fact that any additional intervention component is beneficial to increasing students' achievement. These results support that professional development should have supported workshops or summer institutes offering sustained follow up after the initial professional development (Guskey et al., 2009). These characteristics have been found to have a positive relationship with students' achievement. Overall, the findings of the study confirm the earlier literature on professional development and highlight the importance of content focus, sufficient duration and multiple modalities of providing PD.

Significance of the Study

Effective teachers are lifelong learners. Students' learning is dependent on teachers' knowledge and teachers' growth. There are two types of knowledge that experts in the field have found to have an impact on students' math achievement and have promoted higher student learning. These are content knowledge and pedagogical knowledge of the teachers. However, understanding how teachers' learn and integrate their new knowledge in instruction is not well understood. Since teachers are considered the main change agent when it comes to students' achievement gains, professional development is the vehicle used to increase their knowledge, with the hope of improving student achievement. Many studies show that professional development programs that are focused on content or pedagogy or both; activities that are sustained over time; offering workshops and sustained follow-up support after the initial professional workshop, and duration of program, are positively related to student achievement (Hill, 2007; Yoon et al., 2007; Tournaki et al., 2011; Blank, 2013). The findings of the current meta-analysis confirm that content focus, building professional learning communities, and sufficient time are key to effective PD.

This meta-analysis offers more clarity on some of the issues about effects of professional development and offers guidance about the three effective components (duration, content, and intervention modality). The results of the studies included in this meta-analysis found that PD is most effective when professional development programs are implemented over multiple years. It was not as effective for one academic year as with multiple years and had no effect for one time or short-term duration. This evidence supports current theory that longer duration professional development programs have the most impact on students' achievement. Secondly, this study illustrates that intervention focused on content only had the largest impact on students' achievement, followed by content and pedagogy. On the other hand, pedagogy alone had no effect on students' achievement. Current theory does support, that content or content and pedagogy or both can have a positive impact on students' learning; some experts argue that professional development programs that include both components are more likely to lead to higher student gain than one or the other. Lastly, the program intervention modality showed that workshop plus some other support strategy besides coaching had the largest impact on student learning, followed by workshop plus coaching. Earlier research has shown that professional learning opportunities should be supported and sustained after the initial workshop offering follow-ups.

The evidence offered in this study supports the current theoretical debates in regards to the impact that PD duration, content, and program intervention modality has on student achievement. The present study shed light on two important issues about PD. This study highlights important components of PD that are likely to be successful in improving students' math learning. The other important issue is that there are only a few studies on professional development that measures the changes in student outcomes. Many studies examine the outcomes of PD on teachers but very few studies link PD to student achievement. This meta-analysis attempts to fill that gap in the literature and offers empirical evidence showing that teachers' effectiveness can be increased leading to students' gains when professional development components such as duration of multiple years, focused on content or content and pedagogy, and workshop plus some other support strategies are included in teachers' learning opportunities.

Future Directions

This study points to some directions for future research. Future studies can examine the effects of professional development components (duration, content, and intervention modality) based on the types of professional development programs and make comparisons. More studies should investigate the effects of professional development components (duration, content, and intervention modality) on students' achievement based on difference between rural, urban and suburban schools or different subject areas or in different grades. More studies with stronger designs are needed to examine the relationship of professional development to student gains in learning.

During the analysis of this study the following limitations were noted: a) Sample size, b) Fidelity of Implementation, c) Publication Bias, and d) Study Design. There were three types of sample size limitations. The first was due to the small number of available empirical studies based on professional development with the needed data to calculate the standardized means difference. Some studies had missing data on students' outcomes and had to be eliminated due to the lack of author's response for requested data. The second limitation was the small sample sizes of the groups that were included in some studies with samples less than 20. These limitations can interfere with the analysts' ability to generate generalizable findings. In addition, this limitation can reduce the statistical power of the study. On the other hand, if one study is much larger than the other studies that are included in the meta-analysis, the results can be skewed towards that one study if a fixed effect models is used in the study. Fidelity of implementation is also a limitation since a study which is poorly conducted or designed or both can affect the results of the analysis. It is hard to assess the fidelity with which the PD programs were implemented. For example, a professional development program may look strong on paper but may not be implemented well. The lack of valid and reliable measures of teachers' mathematics knowledge can weaken the empirical evidence linking teacher knowledge and students' learning. Another limitation of meta-analysis method is overcoming the file drawer problem which is publication bias. The publication bias can be a problem in meta-analysis. This issue was handled in the present study by making sure that all possible studies were searched for and included. Lastly, study design is a limitation due to the lack of available randomized studies therefore quasi experimental design studies were included in this analysis.

Conclusions

In conclusion, with the heavy investment of resources by school systems, state and federal departments of education in various forms of PD, it is important to know what components of professional development are effective in increasing teachers' knowledge leading to students' gains. The findings in this study suggested that K-12 mathematics educators and school level decision makers should select or develop professional development programs that consist of multiple year durations, are content focused, or content and pedagogy focused, along with various methods of delivering such as workshops, learning communities and other strategies of support to enhance teaching and learning within their schools or school districts.

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Appendix A-Key Words Search

Key words: professional development of math teachers, math achievement, math content knowledge, pedagogical and teacher quality, professional development and teacher education, professional development and academic achievement, professional development and teachers.

Article Online Searches- Words (EBSCOT guide)

1. Professional development and Math teachers (397)
2. Professional development and math teacher and student achievement (22)
3. Professional development and Math Achievement (11)
4. Professional Development and Math Content Knowledge (1)
5. Professional Development and pedagogical Knowledge and teacher quality (40)
6. Professional Development and math teacher and pedagogical Knowledge (17)
7. Professional Development and math teacher and content knowledge (54)
8. Professional Development and math teacher, and pedagogical and content knowledge, and student achievement (19)
9. Professional Development and math teacher, and pedagogical and content knowledge, and student achievement (4)
10. Professional Development for math teachers, and education, and student achievement (2)

Search-from 2003-2014

- **Education Research Complete from EBSCOhost**

  Education Research Complete indexes citations, abstracts, and full text from journals, books, book chapters, case studies, essays, interviews, conference proceedings, product reviews, and experiments in all areas of education. You can limit to peer-reviewed journals. Jan 2003-December 31, 2014.

  1. Professional development and Math teachers 397 (All)
     - Academic journals (297)
     - Magazine (53)
     - Conference Papers (42)
     - Newspaper (2)
     - Books (1)

  2. Professional development and math teacher and student achievement (22)
     - Academic journals (14)
     - Magazine (4)
     - Conference Papers (4)

  3. Professional development and Math Achievement (11)
     - Academic journals (6)

- Magazine (4)
- Conference Papers (1)

4. Professional Development and Math Content Knowledge (1)
    - Academic journal (1)

5. Professional Development and pedagogical Knowledge and teacher quality (40)
    - Academic journals (37)
    - Magazine (3)

There are a lot of studies that were not based on mathematics in this research. The term math need to be added to the search.

6. Professional Development and math teacher and pedagogical Knowledge (17)
    - Academic journals (16)
    - Magazine (1)

Even though these articles key words are pd, math teacher and pedagogical knowledge this search lead to many articles that expound on how to increase these teacher characteristics but no connection on linking it to student achievement.

7. Professional Development and math teacher and content knowledge (54)
    - Academic journals (42)
    - Magazine (5)
    - Conference Papers (7)

8. Professional Development, and pedagogical and content knowledge, and student achievement (19)
    - Academic journals (17)
    - Magazine (1)
    - Conference (1)

9. Professional Development and math teacher, and pedagogical and content knowledge, and student achievement (4)
    - Academic journals (3)
    - Magazine (1)
10. Professional Development for math teachers, and education, and student achievement (2)
    - Academic journals (1)
    - Magazine (1)

Many of the articles did not have the empirical data needed for my study. They offer theoretical information.

- **ERIC**

  ERIC indexes citations, abstracts, and full text from journal articles, conference and meeting papers, government documents, theses and dissertations, reports, A/V materials, books, and more on all aspects of education. Many documents are available in full text (HTML and PDF). You can limit to peer-reviewed sources for documents published since 2003. January 2003-December 31, 2014

1. Professional development and Math teachers 288 (All)

   - Scholarly Journals (228)
   - Dissertation/Theses (56)
   - Other (6)

2. Professional development and math teacher and student achievement (102)
   - Scholarly Journals (68)
   - Dissertation/Theses (33)
   - Other (1)

3. Professional development and Math Achievement (128)
   - Scholarly Journals (87)-
   - Dissertation/Theses (39)
   - Other (2)

4. Professional Development and Math Content Knowledge (40)
   - Scholarly Journals (28)
   - Dissertation/Theses (11)
   - Other (1)

5. Professional Development and pedagogical Knowledge and teacher quality (85)
   - Scholarly Journals (72)
   - Dissertation/Theses (10)
   - Other (3)

There are a lot of studies that were not based on mathematics in this research. The term math need to be added to the search.

6. Professional Development and math teacher and pedagogical Knowledge (16)

- Scholarly Journals (13)
- Dissertation/Theses (3)

Even though these articles key words are pd, math teacher and pedagogical knowledge this search lead to many articles that expound on how to increase these teacher characteristics but no connection on linking it to student achievement.

7. Professional Development and math teacher and content knowledge (38)
    - Scholarly Journals (26)
    - Dissertation/Theses (11)
    - Other (1)

8. Professional Development, and pedagogical and content knowledge, and student achievement (74)
    - Scholarly Journals (60)
    - Dissertation/Theses (10)
    - Other (3)
    - Report (1)

9. Professional Development and math teacher, and pedagogical and content knowledge, and student achievement (3)
    - Scholarly Journals (2)
    - Dissertation/Theses (1)
10. Professional Development for math teachers, and education, and student achievement (94)
    - Scholarly Journals (61)
    - Dissertation/Theses (32)
    - Other (1)-none

Many of the articles did not have the empirical data needed for my study. They offer theoretical information.

- **Teacher Reference Center**

  Teacher Reference Center indexes abstracts, citations, and full-text articles from academic journals, magazines, directories, biographies, and case studies on all aspects of education. The full-text materials are available in both HTML and PDF formats. You can limit to peer-reviewed sources. January, 2003-December 31, 2014.

  1. Professional development and Math teachers (86)

- Scholarly Journals (62)
- Magazine (24)

2. Professional development and math teacher and student achievement (5)

    - Scholarly Journals (5)

3. Professional development and Math Achievement (1)
    - Scholarly Journals (1)

4. Professional Development and Math Content Knowledge (0)

5. Professional Development and pedagogical Knowledge and teacher quality (11)
    - Scholarly Journals (11)

There are a lot of studies that were not based on mathematics in this research. The term math need to be added to the search.

6. Professional Development and math teacher and pedagogical Knowledge (3)
    - Scholarly Journals (3)

Even though these articles key words are pd, math teacher and pedagogical knowledge this search lead to many articles that expound on how to increase these teacher characteristics but no connection on linking it to student achievement.

7. Professional Development and math teacher and content knowledge (7)
    - Scholarly Journals (7)

8. Professional Development, and pedagogical and content knowledge, and student achievement (10)
    - Scholarly Journals (9)
    - Magazine (1)

9. Professional Development and math teacher, and pedagogical and content knowledge, and student achievement (1)
    - Scholarly Journals (1)

10. Professional Development for math teachers, and education, and student achievement (190)
    - Scholarly Journals (130)
    - Magazine (56)

- Trades (4)

Many of the articles did not have the empirical data needed for my study. They offer theoretical information.

- **APA PsycINFO**
  PsycINFO indexes citations, abstracts, cited references, and some full text from articles, books, dissertations, and reviews on all aspects of psychology. Full text provided as HTML and PDF. You can limit to peer-reviewed sources, age group, classification code, methodology, and population group. January, 2003-December 31, 2014.

1. Professional development and Math teachers (324)

   - Dissertations (187)
   - Scholarly Journals (70)
   - Books (67)

2. Professional development and math teacher and student achievement (100)

   - Dissertations (77)
   - Scholarly Journals (12)
   - Books (11)

3. Professional development and Math Achievement (271)
   - Dissertations (142)
   - Scholarly Journals (32)
   - Books (97)

4. Professional Development and Math Content Knowledge (61)

   - Dissertations (39)
   - Scholarly Journals (9)
   - Books (13)

5. Professional Development and pedagogical Knowledge and teacher quality (42)
   - Dissertations (20)
   - Scholarly Journals (17)
   - Books (5)

There are a lot of studies that were not based on mathematics in this research. The term math needs to be added to the search.

6. Professional Development and math teacher and pedagogical Knowledge (20)
    - Dissertations (13)
    - Scholarly Journals (1)
    - Books (6)

Even though these articles key words are pd, math teacher and pedagogical knowledge this search lead to many articles that expound on how to increase these teacher characteristics but no connection on linking it to student achievement.

7. Professional Development and math teacher and content knowledge (48)
    - Dissertations (30)
    - Scholarly Journals (8)
    - Books (10)

8. Professional Development, and pedagogical and content knowledge, and student achievement (42)
    - Dissertations (27)
    - Scholarly Journals (10)
    - Books (5)

9. Professional Development and math teacher, and pedagogical and content knowledge, and student achievement (18)
    - Dissertations (11)
    - Scholarly Journals (1)
    - Books (6)

Some of the articles used qualitative methodology, which was not supportive for my meta-analysis.

10. Professional Development for math teachers, and education, and student achievement (59)
    - Dissertations (41)
    - Scholarly Journals (10)
    - Books (8)

Many of the articles did not have the empirical data needed for my study. They offered theoretical information.

Appendix B-Non Qualifying Criteria (460 Studies)

				A	B	C	D	E	F	G	H
Paper No.	**Authors**	**Year**	**Title**	**Not K-12 Math PD**	**Teacher Outcome only**	**Theory inadequate quantitative data**	**Qualitative data**	**not suff data for ES**	**Self-Efficacy**	**Perception**	**Method of Study**
1	Patel, Franco, Miura, and Boyd	2012	Including Curriculum Focus in Mathematics PD for Middle School Mathematics Teachers		X						
2	Desimone, Smith, & Ueo	2006	Are Teachers Who Need Sustained Content-Focused PD Getting It? An Administrator's Dilemma	X	X						
3	Jacobs, Koellner, and Funderburk	2012	Problem Solved Middle School Math Instruction Gets Boost from A Flexible Model For Learning					X			
4	O'Dwyer, Masters, Dash, DeKramer, Humez and Russell	2010	e-Learning for Educators Effects of on-Line PD on Teachers and Their Students								
5	Russell, Kleiman, Carey, and Douglas	2009	Comparing Self-paced and Chort-based Online Courses for Teachers		X						
6	Fishman, Konstantopoulos, Kubitskey, Vath, Park, Johnson, and Edelson	2013	Comparing the Impact of Online and Face-to Face PD in the Context of Curriculum Implementation	X							X
7	Russell, Carey, Kleiman, and Venable	2009	Face to Face and Online PD for Mathematics Teachers: A Comparative Study		X						
8	Fisher, Schumaker, Culbertson, & Deshler	2010	Effects of a Computerized PD on Teacher and Student Outcomes	X							X
9	Brown, Faughn, Kent, & Tuba	No Year	Supporting Beginning Mathematics Teachers with Technology-based PD					X			
10	Santagata and Angelici	2010	Studying the Impact of the Lesson Analysis Framework on Preservice Teachers' Abilities to Reflect on Videos of Classroom Teaching	X							X
11	Seidel, Sturmer, Blomberg, Kobarg, and Schwindt	2011	Teacher learning from analysis of Video classroom situations: Does it make a difference whether teachers observe their own teaching or that of others?	X	X						X
12	Sherin, Han	2004	Teacher learning in the context of a Video Club		X			X			
13	Sherin and Van Es	2009	Effects of Video club Participation on Teachers' Professional Vision		X						
14	Zhang, Lunderberg, Koehler, and Eberhardt	2011	Understanding affordances and Challenges of three types of video for teacher PD	X	X						X
15	Penuel, Fishman, Yamaguchi, and Gallagher	2007	What Makes PD Effective? Strategies That Foster Curriculum Implementation	X	X					X	
16	Garet, Porter, Desimone, Birman & Yoon	2001	What Makes PD Effective? Results from a National Sample of Teachers								

17	Hill, Ball	2004	Learning Mathematics for Teaching: Results from California's Mathematics PD Institutes		X						
18	McGatha, Bush, Rakes	2009	The Effects of PD in Formative Assessment on Mathematics Teaching Performance and Student Achievement								
19	Heller, Daehler, Wong, Shinohara, and Miratrix	2012	Differential Effects of Three PD Models on Teacher Knowledge and Student Achievement in elementary Science	X							X
20	Santagata, Kersting, and Stigler	2011	Problem Implementation as a Lever for Change: An Experimental Study of the Effects of a PD program on Students' Mathematics Learning								
21	Harris & Sass	2011	Teacher training, teacher quality and student achievement	X							
22	Cobb, Wood, Yackel, Nicholls, Wheatley, Trigatti, and Perlwitz	2001	Assessment of a Problem-Centered Second-grade Mathematics Project								X
23	Darling-Hammond, Wei, Andree, Richardson, and Orphanos	2009	Professional Learning in The Learning Profession: A Status Report on Teacher Development in the United States					X			
24	Huffman & Thomas	2003	Relationship Between PD, Teachers, Instructional Practices, and the Achievement of Students in Science & Mathematics					X			
25	Kennedy	1998	Form and Substance in Mathematics and Science PD	X							X
26	Ross, Bruce, Hogaboam-Gray	2006	The Impact of a PD Program on Student Achievement in Grade 6 mathematics								
27	Saxe, Gearhart, Nasir	2001	Enhancing Students Understanding of Mathematics: A Study of Three Contrasting Approaches to PD								X
28	Jacob, Lefgren	2004	The Impact of Teacher Training on Student Achievement: Quasi-Experimental Design	X							
29	Desimone, Porter, Garet, Yoon and Birman	2002	Effects of PD on Teacher's Instruction: Results from a three-year longitudinal study		X						
30	Marra, Arbaugh, Lannin, Abell, Ehlert, Smith, Merle-Johnson, Rogers	2011	Orientations to PD Design and Implementation: Understanding their Relationship To PD Outcomes Across Multiple Projects		X						
31	Bell, Wilson, Higgins, McCoach	2010	Measuring the Effects of PD on Teacher Knowledge: The Case of Developing Mathematical Ideas		X						
32	Blank & De las Alas	2009	Effects of Teacher PD on Gains in Student Achievement: How Meta-Analysis Provides Scientific Evidence Useful to Education Leaders								X
33	Hill and Ball	2005	Effects of Teachers' Mathematical Knowledge for Teaching on Student Achievement								
34	Telese	2012	Middle School Mathematics Teachers' PD and Student Achievement								
35	Yoon, Duncan, Wen-Yu Lee, Scarloss, and Shapley	2007	Reviewing the Evidence on how teacher PD affects student achievement								

36	Heller, Curtis, Rabe-Hesketh, Clarke, & Verbencoeur	2007	The Effects of "Math Pathways and Pitfalls" on student mathematics Ach.								
37	Creemers, Kyriakides, and Antoniou	2013	An Experimental Study of Teacher Professional Development Based on the Dynamic Integrated Approach					X			X
38	Blank, Smithson, Porter, Nunnaley, and Osthoff	2006	Improving Instruction through Schoolwide PD: Effects of the Data-on-Enacted-Curriculum Model		X			X			
39	McMeeking, Orsi, and Cobb	2012	Effects of a Teacher PD Program on the Mathematics Achievement of Middle School Students					X			
40	Casa, Tinto	2005	Viewing Professional Development Through Different Lenses: Experiences of Two Major Grant Projects					X			
41	Bruce, Esmonde, Ross, Dookie, and Beatty	2010	The effects of sustained classroom-embedded teacher professional learning on teacher efficacy and related student achievement					X			
42	Hristovitch & Mitcheltree	2004	Exploring MS Teachers Pedagogical Content Knowledge of Fractions and					X			
43	OECD	2009	The professional development for teachers					X			
44	Zwiep & Benken	2012	Exploring Teachers' Knowledge and Perceptions Across Mathematics and Science Through Content-Rich Learning Experiences in a PD Setting		X					X	
45	Cave & Brown	2010	When Learning Stakes: Exploration of Role of Teacher Training and PD Schools Elementary Students' Math Achieve								
46	Graham	2007	Improving Teacher Effectiveness through Structured Collaboration: A Case Study of a Professional Learning Community		X						
47	Owston, Sinclair, & Wideman	2008	Blended Learning For Professional Development: An Evaluation Of A Program For Middle School Mathematics And Science Teachers.					X		X	
48	Kleickmann, Richter, Kunter, Elsner, Besser, Krauss, and Baumert	2013	Teachers' Content Knowledge and Pedagogical Content Knowledge: The Role of Structural Differences in Teacher Education	X							
49	Scher & O'Reilly	2009	Professional Development for K–x2 Math and								X
50	Dash, de Kramer, O'Dwyer, & Masters	2012	Impact of Online Professional Development on Teacher Quality and Student Achievement in Fifth Grade Mathematics								
51	Smith, Desimone and Ueno	2005	"Highly Qualified" to Do What? The Relationship between NCLB Teacher Quality Mandates and the Use of Reform-Oriented Instruction in Middle School Mathematics	X	X						
52	Thornton, Crim, and Hawkins	2009	The Impact of an Ongoing Professional Development Program on Prekindergarten Teachers' Mathematics Practices	X	X						

53	Bailey	2010	The Impact of Sustained, Standards-Based Professional Learning on Second and Third Grade Teachers' Content and Pedagogical Knowledge in Integrated Mathematics		X						
54	Harrisa, Stevens and Higgins	2011	A Professional Development Model for Middle School Teachers of Mathematics		X						
55	Telese	2012	Middle School Mathematics Teachers' Professional Development and Student Achievement								
56	Carey, Kleiman, Russell, Venable, & Louie	2008	Online Courses for Math Teachers: Comparing Self-Paced and Facilitated Cohort Approaches		X						
57	Alvarez	2008	The Relationship of teacher quality and student achievement in Elementary Schools from the New Year City.	X							
58	Polly, Wang, McGee, Lambert, Martin, and David Pugalee	2014	Examining the Influence of a Curriculum-Based Elementary Mathematics Professional Development Program		X						
59	Polly, Neale, & Pugalee	2014	How Does Ongoing Task-Focused Mathematics Professional Development Influence Elementary School Teachers' Knowledge, Beliefs and Enacted Pedagogies?		X						
60	Campbell, Nishio, Smith, Clark, Conant, Rust, DePiper, Frank, Griffin and Choi	2014	The Relationship Between Teachers' Mathematical Content and Pedagogical Knowledge, Teachers' Perceptions, and Student Achievement	X							
61	Desimone, Smith and Phillips	2013	Linking Student Achievement Growth to Professional Development Participation and Changes in Instruction: A Longitudinal Study of Elementary Students and Teachers in Title I Schools								
62	Krawec and Montague	2014	The Role of Teacher Training in Cognitive Strategy Instruction to Improve Math Problem Solving					X			
63	Broyles	2009	The effect of teacher participation in the gateway institute of algebra on student academic achievement.								
64	Patrick	2014	A meta-analysis of dissertation research on the relationship between professional learning community implementation and student achievement.	X							
65	Spiller		The relationship among professional learning communities, a response to intervention framework and mathematics scores in middle and high schools					X			

66	Allen	2012	The Impact of Professional Learning Communities on Third-Grade Math Scores								
67	Roher	2012	The relationship between the degree of participation in Online Embedded Professional Development communities for high school mathematics teachers and student achievement gains in College Algebra.					X			
68	Wimberley	2013	Teacher collaboration and student achievement.								
69	Baumert, Kunter, Blum, Brunner, Voss, Jordan, Krass, Neubrand, and Tsai	2010	Teachers' Mathematical Knowledge, Cognitive Activation in the Classroom, and Student Progress	X	X	X					
70	Erskine	2010	Raising mathematical achievement starts with the elementary teacher: Recommendations to improve content and pedagogical knowledge of elementary math teachers	X							
71	Walters	2009	Understanding and teaching rational numbers: A critical case study of middle school professional development.		X	X					
72	Lesar	2014	The relationship between grade-level team implementation of professional learning communities and student achievement in math.					X			
73	Jones and Gulek	2010	Characteristics of High-Quality Teachers	X	X						
74	Benken and Brown	2004	Improving Students' Mathematical Understandings: An Exploration Into Teacher Learning In An Urban Professional Development Setting		X	X					
75	McGehee	2005	The Coaching/Mentoring Phase In A Professional Development Partnership Project					X			
76	Meyer and Wilkerson	2007	Lesson Study: The Effects On Teachers and Students In Urban Schools In The United States					X			
77	Poetzl	2005	Developing Teacher Practice Through Video Analysis			X		X			
78	Siegfried, Gordon, and Garcia	2007	Barley In S.T.E.P: How Professional Development Affects Teachers Perspectives and Analysis of Student Work					X		X	
79	Feuerborn, Chinn, and Morlan	2009	Improving mathematics teachers' content knowledge via brief in-service: a US case study		X						
80	Van Haneghah, Pruit, bambert	2009	Mathematics reform in a minority community: Student outcomes								
81	DiNardo	2010	The Impact of Professional Learning Communities on Student Achievement								

82	Krupa	2011	Evaluating the Impact of Professional Development and Curricula Implementation on Student Mathematics Achievement: A Mixed Methods Study								
83	Kuchey, Morrison, Geer	2009	A Professional Development Model for Math and Science Educators in Catholic Elementary Schools: Challenges and Changes								
84	Phelan, Choi, Vendlinski, Baker & Herman	2011	Differential Improvement in Student Understanding of Mathematical Principles Following Formative Assessment Intervention								
85	Friesen & Francis-Poscente	2010	Teaching and learning mathematics with Math Fair, Lesson Study and Classroom Mentorship		X	X		X			
86	Chen & Herron	2014	Going Against the Grain: Should Differentiated Instruction be a Normal Component of Professional Development								
87	Faber, Hardin, Klein-Gardner,Benson	2014	Development of Teachers as Scientists in Research Experiences for Teachers Programs	X	X						
88	Fujii, Toshiakira	2013	Implementing Japanese Lesson Study in Foreign Countries: Misconceptions Revealed	X							X
89	Taylor, Edd	2012	Supporting children's mathematical understanding: professional development focused on out-of-school practices				X	X			
90	Adams & Pegg	2012	Teachers' Enactment of Content Literacy Strategies in Secondary Science and Mathematics Classes	X							
91	Souza, Lopes & Mendonca	2014	Professional Development of Mathematics Teachers Implementing Probabilistic Simulations in Elementary School Classrooms		X						
92	Akiba, Motoko	2012	Professional Learning Activities in Context: A Statewide Survey of Middle School Mathematics Teachers	X							
93	Hartsell, Herron, Fang, Rathod	2009	Effectiveness of Professional Development in Teaching Mathematics and Technology Applications		X						
94	Erbas, Cakiroglu, Beşer & Aydin	2006	Professional Development Through Technology-Integrated Problem Solving: From InterMath to T-Math			X					
95	Lewis & Perry	2014	Lesson Study with Mathematical Resources: A Sustainable Model for Locally-led Teacher Professional Learning		X						
96	Leszczynski, Munakata, Evans & Pizzigoni	2014	Integrating Mathematics and Science: ECOLOGY AND VENN DIAGRAMS	X		X					
97	Brantlinger, Sherin, Linsenmeier	2011	Discussing discussion: a video club in the service of math teachers' National Board preparation.	X							
98	Renninger, Cai, Lewis, Adams, & Ernst	2011	Motivation and learning in an online, unmoderated, mathematics workshop for teachers	X	X						

99	Cady, Aydeniz, & Rearden	2011	E-Learning Environments for Math and Science Teachers		X						
100	Stevens, Harris, Aguirre-Munoz, & Cobbs	2009	A case study approach to increasing teachers' mathematics knowledge for teaching and strategies for building students' math self-efficacy						X		
101	Kester Phillips, Bardsley, Bach & Gibb-Brown	2009	"But I can't Teach Math" The Journey of Middle School Mathematics Teachers and Literacy Coaches Learning to Integrate Literacy Strategies into the Math Instruction	X	X	X					
102	Wilson, Sztajn, Edgington & Confrey	2014	Teachers' use of their mathematical knowledge for teaching in learning a mathematics learning trajectory	X	X	X					
103	Hardre', Slater & Nanny	2010	Redesigning and aligning assessment and evaluation for a federally funded math and science teacher educational program	X							
104	Zehetmeier, Stefan	2014	Availing other disciplines' knowledge about sustainable impact of professional development programmes			X					X
105	Heffernan & Heffernan	2014	The ASSISTments Ecosystem: Building a Platform that Brings Scientists and Teachers Together for Minimally Invasive Research on Human Learning and Teaching	X							
106	Boston, Melissa.	2013	Connecting changes in secondary mathematics teachers' knowledge to their experiences in a professional development workshop		X						
107	Polly, Drew	2004	Enhancing Teacher's Math Knowledge through Learner-Centered Professional Development		X						
108	Ebaeguin & Stephens	2014	Cultural Challenges in Adapting Lesson Study to a Philippines Setting		X						X
109	Prouty, Daniel	2009	Developing Math and Science Teacher Pedagogical Skills Through Electronic Mentorship			X					
110	Kusanagi, Kanako N	2013	The Bureaucratizing of Lesson Study : A Javanese Case	X	X	X					X
111	Zambo, Ron; Zambo, Debby	2008	The Impact of Professional Development in Mathematics on Teachers' Individual and Collective Efficacy: The Stigma of Underperforming		X						
112	Duchaine, Jolivete, & Fredrick	2011	The Effect of Teacher Coaching with Performance Feedback on Behavior-Specific Praise in Inclusion Classrooms	X							
113	Dalehefte, Wendt, Köller, Helene, Pietsch, Döring, Fischer, & Bos	2011	Taking Stock after Nine Years of SINUS at Elementary Schools in Germany: An evaluation of mathematics-related data within the framework of TIMSS 20xx.	X							X
114	Takahash, Akihiko	2014	The Role of the Knowledgeable Other in Lesson Study: Examining the Final Comments of Experienced Lesson Study Practitioners		X	X					X

115	Stone, Alfeld, & Pearson	2008	Rigor and Relevance: Enhancing High School Students' Math Skills Through Career and Technical Education	X							
116	Schoenfeld, Alan H	2014	If you really want to get ahead, get a bunch of theories . . . and data to test them			X					
117	Akarsu & Kaya	2012	Redesigning Effective Methods Courses: Teaching Pre-Service Teachers How to Teach	X							X
118	Taylor, Megan Westwood	2013	Replacing the ‘teacher-proof’ curriculum with the ‘curriculum-proof’ teacher: Toward more effective interactions with mathematics textbooks	X							
119	Kretlow, Wood, & Cooke	2011	Using In-Service and Coaching to Increase Kindergarten Teachers’ Accurate Delivery of Group Instructional Units		X						
120	Kong, & Shi	2009	Process analysis and level measurement of textbooks use by teachers	X							
121	Holmstrom, Annette	2010	DISTRICT FINDS THE RIGHT EQUATION TO IMPROVE MATH INSTRUCTION			X					
122	Patahuddin, Sitti Maesuri	2013	Mathematics teacher professional development in and through internet use: reflections on an ethnographic study		X	X					X
123	Zhou, Jun	2012	Teachers’ Professional Development in the Context of Basic Education Curriculum Reform	X							X
124	Aitken, E. Nola	2007	Preservice Teachers' Results on Grade 6 Provincial Math Achievement Test	X	X	X					X
125	Wilkie, Karina	2014	Upper primary school teachers' mathematical knowledge for teaching functional thinking in algebra	X	X	X					X
126	Koellner,Jacobs & Borko	2011	Mathematics Professional Development: Critical Features for Developing Leadership Skills and Building Teachers' Capacity	X	X	X					
127	Beatty, Ian D	2012	Viewing teacher transformation through the lens of cultural-historical activity theory (CHAT)	X	X	X					
128	Visnovska & Cobb	2013	Classroom video in teacher professional development program: community documentational genesis perspective		X						
129	Even, Ruhama	2014	Challenges associated with the professional development of didacticians		X	X					
130	Pryor & Bitter	2008	Using multimedia to teach inservice teachers: Impacts on learning, application, and retention		X	X					
131	Wagner & Herbel-Eisenmann	2014	Mathematics teachers' representations of authority	X							
132	Eiser & Knight	2006	Chapter 6: Knowledge Renewal In The 21ST Century: Developing A Professional Network Of Biology Teachers	X							X
133	Sztajn, Wilson, Edgington & Myers	2014	Mathematics professional development as design for boundary encounters.			X					

134	Verhoef, Tall, Coenders, & Smaalen	2014	The Complexities Of A Lesson Study In A Dutch Situation: Mathematics Teacher Learning			X					X
135	Obara & Sloan	2010	Classroom Experiences With New Curriculum Materials During The Implementation Of Performance Standards In Mathematics: A Case Study Of Teachers Coping With Change		X		X				
136	Huntoon & Baltensperger	2012	Increasing Expertise in Earth Science Education through Master's Education	X							X
137	Huang, Su, & xu	2014	Developing teachers' and teaching researchers' professional competence in mathematics through Chinese Lesson Study.		X	X					
138	Slavit, Nelson & Kennedy	2010	Laser Focus On Content Strengthens Teacher Teams			X					
139	Matteson, Zientek, & Özel	2013	Identifying What In-Service Teachers Want in Professional Development Experiences		X	X	J				
140	Rensaa, Ragnhild Johanne	2012	Investigating engineers' needs as a part of designing a professional development program for engineers who are to become mathematics	X							
141	Neuberger, Jim	2012	Benefits of a teacher and coach collaboration: A case study.	X	X	X					
142	Potari, Despina	2013	The relationship of theory and practice in mathematics teacher professional development: an activity theory perspective		X	X					
143	Heitin, Liana	2011	LIFE EQUATIONS	X							
144	Polly, Drew	2011	Developing Teachers' Technological, Pedagogical, and Content Knowledge (TPACK) through Mathematics Professional Development		X	X					
145	Hunter & Back	2011	Facilitating Sustainable Professional Development through Lesson Study		X		X				
146	Steele, Hillen & Smith	2013	Developing mathematical knowledge for teaching in a methods course: the case of function	X	X						
147	Swan, Pead, Doorman & Mooldijk	2013	Designing and using professional development resources for inquiry-based learning	X	X						
148	Liang, Glaz, DeFranco, Vinsonhaler, Grenier, Cardetti	2013	An examination of the preparation and practice of grades 7-12 mathematics teachers from the Shandong Province in China	X							X
149	Stevens, Harris, Liu & Aguirre-Munoz	2013	Students' ratings of teacher practices		X				X		
150	Potari, Despina	2014	Mathematics teacher knowledge: mathematics in the foreground	X		X					
151	Asghar, Ellington, Rice, Johnson & Prime	2012	Supporting STEM Education in Secondary Science Contexts								X
152	Guberman & Leikin	2013	Interesting and difficult mathematical problems: changing teachers' views by employing multiple-solution tasks		X						

153	Lloyd, Gwendolyn	2013	The ongoing development of mathematics teachers' knowledge and practice: considering possibilities, complexities, and measures of teacher learning	X	X						
154	Levenson, Esther	2013	Tasks that may occasion mathematical creativity: teachers' choices.	X	X						
155	Marshall & Horton	2011	The Relationship of Teacher-Facilitated, Inquiry-Based Instruction to Student Higher-Order Thinking	X		X					
156	Onion, Alice	2011	BOWLAND MATHS -- THE CPD MODULES	X		X					X
157	McAleer & Bangert	2011	Professional Growth Through Online Mentoring: A Study of Mathematics Mentor Teachers		X						
158	Campbell & Malkus	2014	The mathematical knowledge and beliefs of elementary mathematics specialist-coaches	X	X						
159	Brown, Alford, Rollins, Stillisano & Waxman	2013	Evaluating the efficacy of Mathematics, Science and Technology Teacher Preparation academies in Texas	X	X				X		
160	Shriki & Lavy	2012	Perceptions of Israeli mathematics teachers regarding their professional development needs	X						X	X
161	Tyminski, Ledford & Hembree	2010	"What Was Really Accomplished Today?" Mathematics Content Specialists Observe a Class for Prospective K-8 Teachers		X	X					
162	Kensington-Miller, Barbara	2011	Peer mentoring: stories of three mathematics teachers	X	X						
163	Witterholt, Goedhart, Suhre & van Streun	2012	The Interconnected Model of Professional Growth as a means to assess the development of a mathematics teacher	X	X		X				
164	Gellert, Uwe	2008	Routines and collective orientations in mathematics teachers’ professional development	X	X		X				
165	Nipper & Sztajn	2008	Expanding the instructional triangle: conceptualizing mathematics teacher development		X	X					
166	Males, Otten & Herbel-Eisenmann	2010	Challenges of critical colleagueship: examining and reflecting on mathematics teacher study group interactions	X	X						
167	Steele, Michael	2013	Exploring the mathematical knowledge for teaching geometry and measurement through the design and use of rich assessment tasks	X	X	X					
168	Obara, Samuel	2010	Mathematics coaching: a new kind of professional development	X	X	X					
169	Chamberlin, Farmer & Novak	2008	Teachers’ perceptions of assessments of their mathematical knowledge in a professional development course	X	X		X			X	
170	Roche, Anne	2013	Choosing, creating and using story problems: Some helpful hints	X	X	X					X
171	Lloyd, Gwendolyn	2014	Research into teachers' knowledge and the development of mathematics classroom practices	X	X	X					

172	Yakes & Star	2011	Using comparison to develop flexibility for teaching algebra		X						
173	Schifter & Riddle	2004	Students' ideas about math	X	X						
174	Hegedus, Dalton, Roschelle, Penuel, Dickey-Kurdziolek & Tatar	2014	Investigating Why Teachers Reported Continued Use and Sharing of an Educational Innovation After the Research Has Ended		X						
175	Fang, Yanping	2010	Bridging Mathematical Thinking -- Designing Web-based Multimedia Video Cases to Build Online PLC for Singaporean Mathematics Teachers		X						X
176	Chval, Abell, Pareja, Musikul & Ritzka	2008	Science and Mathematics Teachers' Experiences, Needs, and Expectations Regarding Professional Development	X	X						
177	Agyei & Voogt	2011	ICT use in the teaching of mathematics: Implications for professional development of pre-service teachers in Ghana.	X							X
178	Ruthven, Kenneth	2013	From design-based research to re-sourcing 'in the wild': reflections on studies of the co-evolution of mathematics teaching resources and practices	X	X	X					
179	Nelson, Tamara Holmlund	2009	Teachers' collaborative inquiry and professional growth: Should we be optimistic?	X	X		X				
180	Guzman & Kieran	2013	Becoming Aware Of Mathematical Gaps In New Curricular Materials: A Resource-Based Analysis Of Teaching Practice	X		X					
181	de Freitas, Wagner, Esmonde, Knipping, Lunney Borden & Reid	2012	Discursive Authority and Sociocultural Positioning in the Mathematics Classroom: New Directions for Teacher Professional Development	X							
182	Oishi, Lindsay	2011	A NEW AGE FOR ALGEBRA	X	X	X					
183	Huang & Li	2012	What Matters Most: A Comparison of Expert and Novice Teachers' Noticing of Mathematics Classroom Events	X				X			X
184	Tytler,Symington, Darby, Malcolm & Kirkwood	2011	Discourse communities: A framework from which to consider professional development for rural teachers of science and mathematics	X							
185	Slavit & Nelson	2010	Collaborative teacher inquiry as a tool for building theory on the development and use of rich mathematical task	X	X						
186	Stinson, Harkness, Meyer & Stallworth	2009	Mathematics and Science Integration: Models and Characterizations	X	X		X				
187	Brown, Rachael Erikson	2010	Tensions Faced by Mathematics Professional Developers	X							
188	bin Hj Suhaili & Khalid	2011	Mathematics Teachers' Perception of Lesson Study as a Continuous Professional Development Program	X	X					X	

189	Razfar, Aria	2012	Discoursing Mathematically: Using Discourse Analysis to Develop a Sociocritical Perspective of Mathematics Education	X	X		X				
190	Silbey, Robyn	2012	Differentiated development: Not just for students	X	X						
191	Pepin, Gueudet & Trouche	2013	Re-sourcing teachers’ work and interactions: a collective perspective on resources, their use and transformation	X	X						
192	Ross & Bruce	2007	Professional Development Effects on Teacher Efficacy: Results of Randomized Field Trial	X	X				X		
193	Adult Basic Education & Literacy Journal	2009	An Environmental Scan of Adult Numeracy Professional Development Initiatives and Practices	X	X						
194	Lepik & Kaljas	2009	Facilitating Change In Teachers' Views Of Teaching Mathematics		X	X					
195	Trgalová & Jahn	2013	Quality issue in the design and use of resources by mathematics teachers	X	X						
196	Vălcan, Dumitru	2012	A Method To Determine Of All Non-Isomorphic Groups Of Order x6	X		X					
197	Schoenfeld, Alan	2011	Toward professional development for teachers grounded in a theory of decision making	X		X					
198	Chang, Yu-Liang	2010	A Case Study Of Elementary Beginning Mathematics Teachers' Efficacy Development	X	X				X		
199	Cavanagh, Sean	2008	Essential Qualities Of Math Teaching Remain Unknown	X		X					
200	Bell, Wilson, Higgins & McCoach	2010	Measuring the Effects of Professional Development on Teacher Knowledge: The Case of Developing Mathematical Ideas		X						
201	Planas & Civil	2009	Working with mathematics teachers and immigrant students: an empowerment perspective				X				
202	Yarema, Connie H	2010	Mathematics Teachers' Views of Accountability Testing Revealed through Lesson Study	X	X		X				
203	Adams, Anne	2010	Rehearsal or Reorganization Two Patterns of Literacy Strategy Use in Secondary Mathematics Classes		X		X				
204	Hsu, Kysh, Ramage & Resek	2009	Helping Teachers Un-structure: A Promising Approach					X			
205	Celedón-Pattichis, Sylvia	2010	IMPLEMENTING REFORM CURRICULUM Voicing the Experiences of an ESL/Mathematics Teacher				X	X			
206	Nickerson & Masarik	2010	Assessing Teachers' Developing Interpretive Power: Analyzing Student Thinking				X				
207	Henshon, Suzanna E	2014	Prolific Interdisciplinary Investigator: An Interview With Bharath Sriraman	X							
208	Maaß & Doorman	2013	A model for a widespread implementation of inquiry-based learning	X		X					

209	Gellert & Gonzalez	2011	Teacher Collaboration: Implications for New Mathematics Teachers	X	X		X				
210	McMillen, Hill & Friedland	2010	Literacy Strategies in Mathematics Instruction: A Look at New York State Classrooms	X							
211	Chapman & Heater	2010	Understanding change through a high school mathematics teacher's journey to inquiry-based teaching	X		X					
212	Ball & Knights	2004	COCKCROFT 243 TODAY	X		X					
213	Heirdsfield, Lamb & Spry	2010	Leading Learning within a PLC: Implementing new Mathematics content		X		X				
214	Haggarty, Postlethwaite, Diment & Ellins	2011	Improving the learning of newly qualified teachers in the induction year	X	X						
215	Swan & Swain	2010	The impact of a professional development program on the practices and beliefs of numeracy teachers				X				
216	Goos, Dole & Makar	2007	Designing Professional Development to Support Teachers' Learning in Complex Environments	X		X					
217	Hough, O'Rode, Terman & Weissglass	2007	Using concept maps to assess change in teachers' understandings of algebra: a respectful approach		X						
218	Arbaugh, Fran	2003	Study Groups as a Form of Professional Development for Secondary Mathematics Teachers		X				X		
219	McClain, Dean & Schmitt	2007	Locating Professional Development within Institutional Context: Cases from the Middle Grades	X	X						
220	Idris, Loh Sau Cheong, Nor, Razak & Saad	2007	The Professional Preparation of Malaysian Teachers in the Implementation of Teaching and Learning of Mathematics and Science in English	X							X
221	NSTA Reports	2007	Summer programs	X							
222	Gresalfi & Cobb	2011	Negotiating Identities for Mathematics Teaching in the Context of Professional Development		X	X					
223	Swan & Dixon	2006	The Effects of Mentor-Supported Technology Professional Development on Middle School Mathematics Teachers' Attitudes and Practice	X	X					X	
224	Hauge & Norenes	2009	Changing teamwork practices: video paper as a mediating means for teacher professional development		X						
225	Tan, May	2011	Mathematics and science teachers' beliefs and practices regarding the teaching of language in content learning	X							
226	Polly, Drew	2006	Participants' Focus in a Learner-Centered Technology-Rich Mathematics Professional Development Program	X	X		X				
227	Bergthold, Roddick & Silvas-Centeno	2007	From Professional-Development Participant to Doctoral Candidate: The Journey of One Middle-School Mathematics Teacher		X			X			

228	Arbaugh, Lannin, Jones & Park-Rogers	2006	Examining instructional practices in Core-Plus lessons: implications for professional development	X			X				
229	Gueudet & Trouche	2009	Towards new documentation systems for mathematics teachers?	X	X	X					
230	Ramatlapana, Kim	2009	Provision of in-service training of mathematics and science teachers in Botswana: teachers' perspectives	X						X	X
231	Mushayikwa & Lubben	2009	Self-directed professional development – Hope for teachers working in deprived environments?				X				X
232	Ellington, Whitenack, Inge, Murray & Schneider	2012	Assessing K-5 Teacher Leaders' Mathematical Understanding: What Have the Test Makers and the Test Takers Learned?	X							
233	Faux, Geoff	2004	HAPPY 21st BIRTHDAY COCKCROFT	X							
234	Moyer-Packenham, Bolyard, Oh, Kridler & Salkind	2006	Representations of Mathematics Teacher Quality in a National Program	X							
235	Brefogle, M. Lynn; Spotts, Barbara	2011	Professional development delivered right to your door	X		X					
236	Moreira & David	2008	Academic mathematics and mathematical knowledge needed in school teaching practice: some conflicting elements	X	X	X					
237	Marrongelle & Larsen	2006	Generating mathematical discourse among teachers: The role of professional development resources		X			X			
238	Orrill, Chandra Hawley	2006	What Learner-Centered Professional Development Looks Like: The Pilot Studies of the InterMath Professional Development Project		X	X					
239	Nathan, Mitchell	2004	Confronting Teachers' Beliefs About Students' Algebra Development: An Approach for Professional Development	X				X		X	
240	Meletiou-Mavrotheris & Serradó Bayés	2012	Distance Training of Mathematics Teachers: The Early Statistics Experience.		X	X					X
241	Goos, Merrilyn	2014	Creating opportunities to learn in mathematics education: a sociocultural perspective	X		X					
242	Driscoll, Egan, DiMatteo, Rachel & Nikula	2009	Fostering Geometric Thinking in the Middle Grades: Professional Development for Teachers in Grades 5-10		X	X					
243	Tirosh, Tsamir, Levenson, Barkai & Tabach	2014	Using video as a tool for promoting inquiry among preschool teachers and didacticians of mathematics	X							
244	De Geest, Els	2011	Roles of research utilisation in the professional development of mathematics teachers		X		X				

245	Barnes, Hodge, Parker & Koroly	2006	The Teacher Research Update Experience: Perceptions of Practicing Science, Mathematics, and Technology Teachers	X	X		X			X	
246	Andersson, Annica	2011	A 'Curling teacher' in mathematics education: teacher identities and pedagogy development	X			X				
247	Groves & Doig	2014	International Perspectives on Japanese Lesson Study							X	
248	Lachance & Confrey	2003	Interconnecting Content and Community: A Qualitative Study of Secondary Mathematics Teachers				X				
249	Sato, Ruth Chung Wei & Darling-Hammond	2008	Improving Teachers' Assessment Practices Through Professional Development: The Case of National Board Certification	X							
250	Fried & Amit	2005	A Spiral Task as a Model for In-service Teacher Education	X	X						
251	NSTA Reports	2009	Students Gain From Teacher Development			X					
252	Bradley, Paul	2012	Creative Tension			X					X
253	Barton & Paterson	2013	Does Mathematics Enhance Teaching? Does Summer Hiking Tone Winter Thighs?	X	X						
254	Mali, Angeliki	2014	Lecturers' use of generic examples: the generic set	X	X						
255	Bennison & Goos	2010	Learning to Teach Mathematics with Technology: A Survey of Professional Development Needs, Experiences and Impacts.	X	X						X
256	Bartell, Tonya Gau	2013	Learning to Teach Mathematics for Social Justice: Negotiating Social Justice and Mathematical Goals	X							
257	Huang, Li, Zhang & Li	2011	Improving teachers' expertise in mathematics instruction through exemplary lesson development	X	X		X				
258	Meletiou-Mavrotheris & Mavrotheris	2007	Online Communities of Practice Enhancing Statistics Instruction: The European Project Early Statistics	X							
259	Abell, Lannin, Marra, Ehlert, Cole, Lee, Park Rogers & Wang	2007	MULTI-SITE EVALUATION OF SCIENCE AND MATHEMATICS TEACHER PROFESSIONAL DEVELOPMENT PROGRAMS: THE PROJECT PROFILE APPROACH	X							
260	Cwikla, Julie	2003	The Importance of Setting Learning Goals to Investigate the Effectiveness of Teacher Professional Development	X							
261	Garza & Werner	2014	Preparing mathematics and science teachers through a residency program: perceptions and reflections	X							

262	Obara & Sloan	2009	The Evolving Role of a Mathematics Coach During the Implementation of Performance Standards	X		X					
263	Dodeen, Abdelfattah, Shumrani & Hilal	2012	The Effects of Teachers' Qualifications, Practices, and Perceptions on Student Achievement in TIMSS Mathematics: A Comparison of Two Countries	X	X					X	
264	Skerrett & Sevian	2010	Identity and biography as mediators of science and mathematics faculty's involvement in K-x2 service	X	X						
265	Ejersbo & Leron	2010	TAxICAB	X							
266	George, Michael	2014	Facilitating an Engaging Workshop for Adjunct Faculty								
267	Cibuiskaitė, Nijolė	2009	THE PROBLEMS OF TRIGONOMETRY TEACHING IN SCHOOL AND AT THE UNIVERSITY	X							
268	Gellert, Espinoza & Barbé	2013	Being a mathematics teacher in times of reform	X							
269	Panasuk & Bolinger Horton	2012	Integrating History of Mathematics into Curriculum: What are the Chances and Constraints?	X						X	
270	Mojica, Lee & Berenson	2005	Supporting the Middle School Mathematics Teacher in Pursuit of National Board Certification.				X	X			
271	Akkoç & Ozmantar	2013	Use of multiple representations in technology rich environments.	X	X						X
272	Patkin & Gesser	2009	The story of leading mathematics teachers from teacher-trainees to key positions	X	X					X	X
273	Kul, Umit	2012	Turkish mathematics teachers' experiences with Geogebra activities: changes in beliefs		X						
274	Dalgarno & Colgan	2007	Supporting novice elementary mathematics teachers' induction in professional communities and providing innovative forms of pedagogical content knowledge development through information and communication technology		X		X				
275	Niess, Ronau, Shafer, Driskell, Harper, Johnston, Browning, Özgün-Koca & Kersaint	2009	Mathematics Teacher TPACK Standards and Development Model	X							
276	Higgins & Bonne	2011	Configurations of Instructional Leadership Enactments That Promote the Teaching and Learning of Mathematics in a New Zealand Elementary School	X							X
277	Miller & Glover	2007	Into the unknown: the professional development induction experience of secondary mathematics teachers using interactive whiteboard technology.	X							
278	Staples, Megan E	2012	Justification as a teaching and learning practice: Its (potential) multifacted role in middle grades mathematics classrooms	X							
279	Wainer & Robinson	2006	Profiles in Research: Julian Cecil Stanley	X							

280	Benken, Babette M	2007	Breaking New Ground: Utilizing an On-site University Field Experience to Facilitate Teacher Development		X			X			
281	Leikin, Roza	2003	Problem-Solving Preferences of Mathematics Teachers: Focusing on Symmetry		X						
282	Kimmins & Chappell	2004	Positioning Teachers to Enact Standards-Based Instruction	X	X	X					
283	García, Sánchez & Escudero	2007	Learning Through Reflection in Mathematics Teacher Education	X	X	X					
284	Holcombe, Amy	2009	MORE THAN THE SUM OF ITS PARTS	X							
285	Barrett, Nenduradu & Olson	2005	Integrating Mathematics of Measurement Into Elementary Teachers' Pedagogy: Collaborative Design as a Professional Development Tool	X			X				
286	Watson, Caney, Beswick & Skalicky	2005/2006	Profiling Teacher Change Resulting from a Professional Learning Program in Middle School Numeracy		X	X					
287	Taylor, Ferrell & Hopkins	2007	Professional Development for Mathematics Teachers: A Team Approach	X		X					
288	Brown & Coles	2010	Mathematics teacher and mathematics teacher educator change-insight through theoretical perspectives.	X		X					
289	Cameron, Blanchette, Francis, Fuentes & Rivera-Deliz	2012	CHAPTER x3: The Role of Communities of Practice in Developing Teacher Leadership	X							
290	Teaching Children Mathematics	2014	One Program, One Participant, Many New Leaders	X							
291	Applebaum & Leikin	2007	Looking back at the beginning: Critical thinking in solving unrealistic problems	X							
292	Kelly, Berry & Battersby	2007	Developing teacher expertise: teachers and students doing mathematics together	X			X				
293	Petty, Teresa M	2007	Empowering Teachers: They Have Told Us What They Want and Need to be Successful			X					
294	Rasmussen, Chris	2008	Multipurpose Professional Growth Sequence: The catwalk problem as a paradigmatic example			X					
295	Coles, Alf	2011	USING VIDEO AND FILM			X					
296	Roddick & Bergthold	2004	Sixth Grade Mathematics Teachers in Transition: A Case Study		X						
297	Polly, Drew	2004	TIM and InterMath: Two Approaches to Learner-Centered Professional Development		X	X					
298		2009	Transforming Secondary Mathematics Teaching: Increasing the Cognitive Demands of Instructional Tasks Used in Teachers' Classrooms					X			
299	Speer, Gutmann & Murphy	2005	MATHEMATICS TEACHING ASSISTANT PREPARATION AND DEVELOPMENT	X							X

300	Bossé & Rider	2005	Investigating Distance Professional Development: Lessons Learned from Research		X		X				
301	Agudelo-Valderrama, Cecilia	2008	The power of Colombian mathematics teachers' conceptions of social/institutional factors of teaching	X	X					X	
302	Alvermann, Friese, Beckmann & Rezak	2011	Content area reading pedagogy and domain knowledge: a Bourdieusian analysis	X							
303	Amit, Fried & Satianov	2004	Classroom note: Area of convex regions as a unifying theme for the review of some topics in first-year college courses	X							X
304	Arbaugh & Brown	2005	Analyzing Mathematical Tasks: A Catalyst for Change?		X		X				
305	Arbaugh, Lannin, Barker & Jones	2005	Curriculum-Specific Professional Development: A Phenomenographical Study of Teachers' Perceptions		X		X			X	
306	Arbaugh, Fran	2003	Study Groups: Professional Growth through Collaboration	X		X					
307	Artzt & Curcio	2007	TIME 2000: A Mathematics Teaching Program	X							X
308	Arvold, Bridget	2005	Reflection Gone Awry	X							
309	Asquith, Stephens, Knuth & Alibali	2007	Middle School Mathematics Teachers' Knowledge of Students' Understanding of Core Algebraic Concepts: Equal Sign and Variable	X	X	X					
310	Bafumo, Mary Ellen	2005	Making Math Meaningful	X							
311	Bartell, Tonya Gau	2006	Striving for equity in mathematics education: Learning to teach mathematics for social justice	X							
312	Bartell & Meyer	2008	Addressing the Equity Principle in the Mathematics Classroom		X						
313	Becket & Gallagher	2008	NEWS FROM ATM	X							X
314	Benson, Chauvot, & Hernandez	2007	Prospective and Practicing 4-12 Mathematics Teachers' Thinking within a University Course about Proportional Reasoning		X					X	
315	Bildungspolitik und Bildungswesen	2006	Educational policy and educational system	X							
316	Blair, Richelle	2007	Change: It Comes Straight from the Heart	X							
317	Bol & Berry	2005	Secondary Mathematics Teachers' Perceptions of the Achievement Gap		X		X			X	
318	Borja, Rhea R	2006	OUT AND ABOUT: EXTERN PROGRAMS AT A GLANCE	X							
319	Breyfogle, Lynn	2005	Reflective states associated with creating inquiry-based mathematical discourse		X			X			

320	Brodesky, Gross, McTigue & Tierney	2004	Planning Strategies for Students with Special Needs: A Professional Development Activity		X						
321	Brown, Emily Ann	2011	U.S. lacks competitive math teacher prep, expert says	X							
322	Brown, Hanley, Darby & Calder	2007	Teachers' conceptions of learning philosophies: discussing context and contextualizing discussion.	X		X					
323	Buckley & Crockett	2007	Coflection in Professional Development: Equity-based Practices in Mathematics Education	X				X			
324	Burks, Heidenberg, Leoni & Ratliff	2009	Supporting the Motivators: A Faculty Development Issue	X							
325	Burns, Marilyn	2004	A can of Coke leads to a piece of pi		X						
326	Chae, Imm, & Stylianou	2007	Deepening practice: Emerging conceptions of representation among secondary mathematics teachers		X	X					
327	Chamblee, Slough & Wunsch	2008	Measuring High School Mathematics Teachers' Concerns About Graphing Calculators and Change: A Year Long Study		X						
328	Chapman, Leonard, Burciaga & Jernigan	2013	A Tale of Three Teachers		X						
329	Chauvot, Jennifer B	2009	Grounding practice in scholarship, grounding scholarship in practice: Knowledge of a mathematics teacher educator–researcher	X							
330	Chauvot, Jennifer	2005	Epistemological Development and Mathematics Teacher Learning			X					
331	Chauvot, Ice, Sanchez, Kastberg, Leatham, Lovin & Norton III	2007	A Collaborative to Study Beliefs of Mathematics Teacher Educators	X						X	
332	Che, Megan	2008	Domestic and international power relations in a Cameroonian mission school system	X						X	
333	Cockburn, Anne	2011	Exploring complex issues: Insights from classrooms, courses and conversations	X							
334	Cohen, Brian	2012	I Blame Mickey Jo!	X							
335	Contreras & Martinez-Cruz	2009	Representing, Modeling, and Solving Problems in Interactive Geometry Environments	X							
336	Crespo, Sandra	2006	Elementary Teacher Talk in Mathematics Study Groups	X			X				
337	Cwikla, Julie	2004	Less experienced mathematics teachers report what is wrong with their professional support system	X							
338	Cwikla, Julie	2005	A Vehicle for Mathematics Lessons: In-Service Teachers Learning to Use PDAs in Their Classrooms	X							
339	Davis, Caroline	2003	Academe to aid math's revival	X							

340	DEMİR & BOZKURT	2011	Primary Mathematics Teachers' Views about Their Competencies Concerning the Integration of Technology		X					X	
341	DeSimone & Parmar	2006	Middle School Mathematics Teachers' Beliefs About Inclusion of Students with Learning Disabilities	X						X	
342	District Administration	2003	The State of Science and Math Teachers	X							
343	Doerr & Thompson	2004	Understanding Teacher Educators and Their Pre-service Teachers through Multi-media Case Studies of Practice	X							X
344	Donoghue, Eileen	2006	The Education of Mathematics Teachers in the United States: David Eugene Smith, Early Twentieth-Century Pioneer	X							
345	Dossey, John A	2006/2007	PRESIDENT'S choice	X							
346	Ensign, Jacque	2012	TEACHER-INITIATED Differentiation	X		X					
347	Ersoy, Yaşr	2005	THE VIEWS OF SCIENCE LYCEUM MATHEMATICS TEACHERS-I: THE MEDIA OF MATHEMATICS TEACHING AND SOME CONSTRAINTS	X							X
348	Feryok, Anne	2009	Activity theory, imitation and their role in teacher development	X							
349	Feuerborn, Chinn & Morlan	2009	Improving mathematics teachers' content knowledge via brief in-service: a US case study		X						
350	Fisch, Karl	2008	Bestowing the Gifts of Professional Development	X		X					X
351	Foote, Bartell & Wager	2007	Looking outside the mathematics classroom: Professional Development that Integrates Mathematics and Lived Experiences		X		X				
352	Forgasz, Helen	2006	Teachers, equity, and computers for secondary mathematics learning	X							X
353	French, Doug	2006	Boost your retention, reduce the subtraction	X							X
354	Gabriele & Joram	2007	Teachers' Reflections on Their Reform-Based Teaching in Mathematics: Implications for the Development of Teacher Self-Efficacy	X					X		
355	Gates, Gordon S	2009	In This Issue	X							
356	Gibbons, Rachel	2007	To personalise, just SMILE	X		X					
357	Gill & Boote	2012	Classroom Culture, Mathematics Culture, and the Failures of Reform: The Need for a Collective View of Culture.	X							
358	Givvin, Santagata & Gallimore	2006	Using Research to Create and Evaluate a Professional Development Program: The Case of BreakThrough Mathematics	X							

359	Gningue, Serigne Mbaye	2003	The Effectiveness of Long Term vs. Short Term Training in Selected Computing Technologies on Middle and High School Mathematics Teachers' Attitudes and Beliefs		X					X	
360	Goodall, Gerald	2007	NEWS & NOTES	X							X
361	Goos & Bennison	2008	Surveying the Technology Landscape: Teachers' Use of Technology in Secondary Mathematics Classrooms	X							X
362	Graeber, Newton & Chambliss	2012	Crossing the Borders Again: Challenges in Comparing Quality Instruction in Mathematics and Reading	X							
363	Grimwade, Laura	2006	The InterMath Experience: A Student's Perspective	X							
364	Groth & Burgess	2009	An Exploration of Two Online Approaches to Mathematics Teacher Education		X						
365	Groth, Randall E	2007	Case Studies of Mathematics Teachers' Learning in an Online Study Group		X		X				
366	Gueudet & Trouche	2011	Mathematics teacher education advanced methods: an example in dynamic geometry		X						
367	Hallagan, Jean E	2004	A Teacher's Model of His Students Algebraic Thinking: 'Ways of Thinking' Sheets		X	X					
368	Handal, Cavanagh, Wood & Petocz	2011	Factors leading to the adoption of a learning technology: The case of graphics calculators				X				
369	HANDAL, CAMPBELL, CAVANAGH, PETOCZ & KELLY	2012	Integrating Technology, Pedagogy and Content in Mathematics Education	X							
370	Harkness & Portwood	2007	A Quilting Lesson for Early Childhood Preservice and Regular Classroom Teachers: What Constitutes Mathematical Activity?	X							
371	Herbel-Eisenmann, Drake & Cirillo	2009	"Muddying the clear waters": Teachers' take-up of the linguistic idea of revoicing	X	X		X				
372	Herrelko & Hunn	2006	Ohio's Outstanding Mathematics and Science Teachers Devote Their Summer of Professional Growth		X						
373	Hill, Kapitula & Umland	2011	A Validity Argument Approach to Evaluating Teacher Value-Added Scores	X							
374	Horn, Ilana	2004	Developing Conceptually Transparent Language for Teaching through Collegial Conversations.	X			X				
375	Hristovitch & Mitcheltree	2004	Exploring Middle School Teachers' Pedagogical Content Knowledge of Fractions and Decimals		X			X			
376	Huffman, Thomas & Lawrenz	2003	Relationship Between Professional Development, Teachers' Instructional Practices, and the Achievement of Students in Science and Mathematics	X				X			
377	Hutchison, Laveria F	2012	Addressing the STEM Teacher Shortage in American Schools: Ways to Recruit and Retain Effective STEM Teachers		X		X				

378	Izsák, Andrew	2005	Guest Editorial...Learning to Frame Research in Mathematics Education	X							
379	Jackson, Christa	2013	Elementary Mathematics Teachers' Knowledge of Equity Pedagogy				X				
380	Johnston-Wilder, Sue	2006	FROM THE CHAIR	X							
381	Kahan, Cooper & Bethea	2003	The Role of Mathematics Teachers' Content Knowledge in their Teaching: A Framework for Research applied to a Study of Student Teachers.	X							
382	Kersaint & Berger	2012	CHAPTER 19: Negotiating Cultural Meanings: A Large-Scale Collaboration among Mathematicians, Mathematics Teacher Educators, and Teachers		X						
383	Kleickmann, Richter, Kunter, Elsner, Besser, Krauss & Baumert	2013	Teachers' Content Knowledge and Pedagogical Content Knowledge: The Role of Structural Differences in Teacher Education	X							
384	Kulm, Gerald	2006	Research on Teacher Development	X							
385	Kussoy, Howard	2005	Online courses add up to better math instructors		X						
386	Langham, Sundberg & Goodman	2006	Developing Algebraic Thinking: An Academy Model for Professional Development	X		X					
387	Lavy & Shriki	2008	Investigating changes in prospective teachers' views of a 'good teacher' while engaging in computerized project-based learning	X						X	
388	Leatham, Keith	2006	Viewing Mathematics Teachers' Beliefs as Sensible Systems	X	X	X				X	
389	Leikin, Roza	2004	The wholes that are greater than the sum of their parts: employing cooperative learning in mathematics teachers' education	X	X	X					
390	Levenson, Tsamir & Tirosh	2010	Mathematically based and practically based explanations in the elementary school: teachers' preferences	X							
391	Li & Huang	2008	Chinese elementary mathematics teachers' knowledge in mathematics and pedagogy for teaching: the case of fraction division	X	X					X	
392	Limin Chen, Van Dooren, Qi Chen & Verschaffel	2011	AN INVESTIGATION ON CHINESE TEACHERS' REALISTIC PROBLEM POSING AND PROBLEM SOLVING ABILITY AND BELIEFS	X						X	
393	Linnen, Lawrence	2005	The Effects of Coaching on a Teacher and Her Coach: A Multi-Level Action Research Study	X							
394	Love, Eric	2007	Dick Tahta	X							
395	Loveless, Avril	2003	Technology, Pedagogy and Education -- widening the scope	X							

396	Magiera, Jennie	2012	Blended PD: The Best Of Both Worlds	X		X					
397	Mansell, Warwick	2004	Right answers for math?	X							
398	Many Voices	2007	ESOL Online: Schooling Is all About Language	X							
399	Marchand, Pickreign & Howard	2005	An Analysis of the Performance Gap Between American Indian and Anglo Students in the New York State Fourth and Eighth Grade Mathematics Assessments	X							
400	Mason, John	2003	Reader Commentary, Seeing worthwhile things	X							
401	Mathematics Teacher	2005	Will This Be the Year…?	X							
402	Meier, Rich & Cady	2006	Teachers' use of rubrics to score non-traditional tasks: factors related to discrepancies in scoring		X						
403	Mercer, Lee, Hart, Foletta & Becker	2003	PRODUCTS	X							
404	Meyer & Wilkerson	2007	Lesson Study: The Effects On Teachers and Students In Urban Schools In the United States				X	X			
405	Milne, Jonathan	2008	Lecturers need more class time, say trainees	X							X
406	Murray, Jenny	2003	UPDATE From ATM's Professional Officer	X		X					
407	Nathan & Petrosino	2003	Expert Blind Spot Among Preservice Teachers	X							X
408	Newton & Newton	2007	Could Elementary Mathematics Textbooks Help Give Attention to Reasons in the Classroom?	X							
409	Niess, Margaret L	2006	Guest Editorial: Preparing Teachers to Teach Mathematics With Technology.	X							
410	Njuguna, Wangui	2012	Expert: Pay attention to content in STEM PLCs	X							
411	Njuguna, Wangui	2011	STEM teacher effectiveness relies on analysis, creativity	X							
412	Noormohamed, Fayaz	2005/2006	PROVE IT!: Importance of Proof Thinking, in Math Education	X							
413	Noyes, Andrew	2006	Using metaphor in mathematics teacher preparation	X							X
414	O'Donnell, Barbara	2006	On Becoming a Better Problem-Solving Teacher				X				
415	O'Donnell & Taylor	2006/2007	A Lesson Plan as Professional Development? You've Got to Be Kidding!			X					
416	Panizzon & Pegg	2008	ASSESSMENT PRACTICES: EMPOWERING MATHEMATICS AND SCIENCE TEACHERS IN RURAL SECONDARY SCHOOLS TO ENHANCE STUDENT LEARNING	X							X

417	Pierce & Ball	2009	Perceptions that may affect teachers' intention to use technology in secondary mathematics classes	X						X	
418	Pittman, Koellner & Brendefur	2007	Analyzing teacher content knowledge of probability: The maze problem		X		X				
419	Poetzl, Christina	2005	Developing Teacher Practice Through Video Analysis		X	X					
420	T. G. ASEE Prism	2006	Rolling Off Its First Ph.D	X							
421	Remillard & Bryans	2004	Teachers' Orientations Toward Mathematics Curriculum Materials: Implications for Teacher Learning					X			
422	Richardson, Sandra	2009	Mathematics Teachers' Development, Exploration, and Advancement of Technological Pedagogical Content Knowledge in the Teaching and Learning of Algebra		X						
423	Richardson & Wilkinson	2006	Challenges of Instructing Secondary English Language Learner Students in Mathematics: A Survey of Texas Teachers	X							
424	Ricks, Thomas	2011	Process reflection during Japanese lesson study experiences by prospective secondary mathematics teachers		X						
425	Ritzhaupt, Higgins & Allred	2010	Teacher Experiences on the Integration of Modern Educational Games in the Middle School Mathematics Classroom		X						
426	Roesken, Pepin & Toerner	2011	Beliefs and beyond: affect and the teaching and learning of mathematics							X	
427	Rommel-Esham, Katie	2011	The President's Message	X							
428	Ruthven & Hofmann	2013	Chance by design: devising an introductory probability module for implementation at scale in English early-secondary education	X							
429	SAVARD, FREIMAN, THEIS & LAROSE	2013	DISCUSSING VIRTUAL TOOLS THAT SIMULATE PROBABILITIES: WHAT ARE THE MIDDLE SCHOOL TEACHERS' CONCERNS?	X							X
430	Schoenfeld, Alan H	2009	Working with Schools: The Story of a Mathematics Education Collaboration	X							
431	Scientific Principals	2012	Enhance Your Content Knowledge	X							
432	Searle, Jeff	2011	Investigating the impact of the Further Mathematics Network.	X							
433	Silbey, Robyn	2011	Steering the PD ship	X							
434	Silver, Charalambous, Strawhun & Stylianides	2006	Focusing On Teacher Learning: Revisiting the Issue of Having Students Consider Multiple Solutions for Mathematics Problems	X							

435	Simon, Martin	2013	Promoting fundamental change in mathematics teaching: a theoretical, methodological, and empirical approach to the problem	X							
436	Skinner, Jon	2011	Teachers, Teaching with Technology	X							
437	Slater, Jon	2005	Charter could boost science staff's pay	X							X
438	Speer, Natasha M	2008	Connecting Beliefs and Practices: A Fine-Grained Analysis of a College Mathematics Teacher's Collections of Beliefs and Their Relationship to His Instructional Practices	X						X	
439	Sturdivant, Dunham & Jardine	2009	Preparing Mathematics Teachers for Technology-Rich Environments	X		X					
440	Stylianides & Ball	2008	Understanding and describing mathematical knowledge for teaching: knowledge about proof for engaging students in the activity of proving	X		X					
441	Stylianou, Despina	2010	Teachers' conceptions of representation in middle school mathematics	X							
442	Sullivan, Clarke & Clarke	2009	Converting Mathematics Tasks to Learning Opportunities: An Important Aspect of Knowledge for Mathematics Teaching		X		X				
443	Swan, Malcolm	2006	Designing and using research instruments to describe the beliefs and practices of mathematics teachers	X							
444	Taylor, Mark P	2004	Encouraging Professional Growth and Mathematics Reform through Collegial Interaction	X							
445	Teacher Professional Development	2011	Math: It's in the Cards	X							
446	TEACHER development	2007	NOTES	X							
447	Tyminski, Haltiwanger, Zambak, Horton & Hedetniemi	2013	Developing Inquiry Practices in Middle Grades Mathematics Teachers: Examining the Introduction of Technology	X	X					X	
448	UMPHREY, Lee	2009	Comedy for Teachers	X							
449	van Es & Sherin	2008	Mathematics teachers' "learning to notice" in the context of a video club		X		X				
450	Walker, Dorothy	2004	It's a numbers game	X							
451	Walshaw & Anthony	2007	Policy Implementation: Integrating the Personal and the Social		X	X					
452	Walter & Gerson	2004	Lyn's Representation of Slope as an Iterative Process			X		X			
453	What Works in Teaching & Learning	2008	Math specialists a 'practical alternative' to elementary improvement	X							

454	White, Sztajn, Hackenberg & Allexsaht-Snider	2004	Building a Mathematics Education Community that Facilitates Teacher Sharing in an Urban Elementary School		X		X				
455	Wilcox & Jones	2004	A Tool for the Teaching Principle	X							
456	Wiles, Peter	2007	The Mathematics of Children's Thinking: An Examination of Teacher Educators' Use of Invented Strategies in a Mathematics Content Course for Perspective Elementary Teachers	X			X				
457	Wilson, Morris & Manon	2005	Evolving Research Frameworks: Videotapes as a Tool for Dialogue	X	X						
458	Winds of Change Magazine	2011	Wilma Godwin	X							
459	Zilliox & Fernandez	2004	Lesson Study in Preservice Teacher Education								X
460	Blank, Smithson, Porter, Nunnaley, and Osthoff	2007	Improving Instruction through Schoolwide PD: Effects of the Data-on-Enacted-Curriculum Model		X			X			
Total				**272**	**182**	**90**	**48**	**40**	**7**	**32**	**61**

Green represents studies that are too old to qualify (3)
Yellow represents studies that did not qualify out of the 31 studies (15)
Light blue represents studies that qualified out of the 31 (16)

Studies Non Qualifying Criteria

There were a total of 460 studies reviewed 16 studies qualified for the Meta-Analysis. The 8 criteria listed below were reasons for studies not qualifying to be included in this study. Some studies may have fallen in more than one category.

G- Studies were not K-12 mathematics professional development-272

- The words math teachers and professional development were mentioned in some studies but no professional development learning opportunities were offered.
- Some studies focused on some form of professional development opportunities but were not aiming to increase teachers' mathematics content knowledge or pedagogical content knowledge or both.
- Some studies were not focus on professional development models but offered suggestions that professional development was needed.
- Some studies focused on the evaluation or assessment of professional development programs.

H-The study did not provide any data for student achievement (teachers' outcomes only)-182

I-The study examined the theory of professional development with inadequate quantitative data-90

J-The study provided qualitative data on student performance-48

K-The study did not provide adequate statistical data for calculating effect size-40

L-The study examined teachers' self-efficacy towards professional development-7

M-The study examined teachers and students perception (beliefs) of teaching and learning-32

N-The method or criteria used to conduct the study did not qualify (meta-analysis, study out dated, not conducted in United States or Canada, preservice teachers, or science)-61

Appendix C-Key Elements Matrix (83 Studies)

Paper No.	Author(s)	Year	Title	Source	Abstract	Found in	Have
1	Patel, Franco, Miura, and Boyd	2012	Including Curriculum Focus in Mathematics PD for Middle School Mathematics Teachers	School Science & Mathematics	PD CMP workshops focused on Connected Math, a particular curriculum utilized or being considered by the middle-school mathematics teachers involved in the study. Pre- and post-mathematics content knowledge assessments indicated that engaging middle-school teachers in the curriculum materials using pedagogy that can be used with their middle-school students not only solidified teachers' familiarity with such strategies, but also contributed to their understanding of the mathematics content.	EBSCOT, ERIC, TRC	Yes
2	Desimone, Smith, & Ueo	2006	Are Teachers Who Need Sustained Content-Focused PD Getting It? An Administrator's Dilemma	Educational Administration Quarterly	PD Content Focus-2000 NAEP data. The results indicate that teachers with strong content knowledge in mathematics measured by type of degree in mathematics and self-reported preparedness to teach different topics in mathematics—are more likely to take sustained content-focused pd than teachers with weak content knowledge in mathematics. Thus, professional development is primarily serving teachers with already strong content area expertise in mathematics, rather than addressing content knowledge gaps for teachers less prepared to teach mathematics.	EBSCOT, ERIC	Yes
3	Jacobs, Koellner, and Funderburk	2012	Problem Solved Middle School Math Instruction Gets Boost from A Flexible Model For Learning	Journal of Staff Development	Problem Solving Cycle PD Model-had a significant impact on teachers' content knowledge, these data have only recently been analyzed and have not yet been widely seen by teachers, principals, or others in the district (Koellner, Jacobs, & Borko, 2011). In other words, the scalability and sustainability of the problem-solving cycle occurred before the proven effectiveness of the model.	ERIC	Yes
4	O'Dwyer, Masters, Dash, DeKramer, Humez and Russell	2010	e-Learning for Educators Effects of on-Line PD on Teachers and Their Students	inTASC Report	Randomized Trials On-Line PD- examined the effect that a series of three OPD courses had on teachers' knowledge and instructional practices, and subsequent effects on student achievement. Collectively, the four trials provide strong evidence that participation in a coordinated series of three OPD workshops has positive effects on teachers' instructional practices and content knowledge. Evidence that a series of online PD courses that target specific student learning needs can have positive effects on teacher knowledge and instructional practices. Importantly, this study provides a body of evidence that teachers' participation in a coordinated series of OPD courses have effects that translate into improvements in targeted student outcomes.	Backward Hill 2013, EBSCOT	Yes

5	Russell, Kleiman, Carey, and Douglas	2009	Comparing Self-paced and Cohort-based Online Courses for Teachers	Journal of Research on Technology in Education	Online and teachers outcomes-investigated whether online professional development courses with different levels of support have different impacts on teacher outcomes. Variations of an online course for middle school algebra teachers were created for four experimental conditions. One was a highly supported condition, with a math education instructor, an online facilitator, and asynchronous peer interactions among participants available as participants worked through the course together. Another was a self-paced condition, in which none of the supports were available. The other two conditions provided intermediate levels of support. All conditions showed significant impact on teachers' mathematical understanding, pedagogical beliefs, and instructional practices. Surprisingly, the positive outcomes were comparable across all four conditions.	Backward Hill 2013, EBSCOT	Yes
6	Fishman, Konstantopoulos, Kubitskey, Vath, Park, Johnson, and Edelson	2013	Comparing the Impact of Online and Face-to Face PD in the Context of Curriculum Implementation	Journal of Teacher Education	Randomized Experiment to examine differences in teacher and student learning from professional development (PD) in two modalities: online and face-to-face. The study explores whether there are differences in teacher knowledge and beliefs, teacher classroom practice, and student learning outcomes related to PD modality. Comparison of classroom practice and student learning outcomes, normally difficult to establish in PD research, is facilitated by the use of a common set of curriculum materials as the content for PD and subsequent teaching. Findings indicate that teachers and students exhibited significant gains in both conditions, and that there was no significant difference between conditions.	Backward Hill 2013, EBSCOT	Yes
7	Russell, Carey, Kleiman, and Venable	2009	Face to Face and Online PD for Mathematics Teachers: A Comparative Study	Journal of Asynchronous Learning Networks	Compared PD Course Online and face to face format. The effects examined included changes in teachers' pedagogical beliefs, instructional practices, and understanding of teaching number-sense and related mathematical concepts. The study randomly assigned participants to either the online or the face-to-face format and employed the same instructors, reading material, and instructional activities for both formats of the course. Both formats of the course showed significant impacts on teachers' mathematical understanding, pedagogical beliefs, and instructional practices.	Backward-Hill 2013-EBSCOT	Yes

8	Fisher, Schumaker, Culbertson, & Deshler	2010	Effects of a Computerized PD on Teacher and Student Outcomes	Journal of Teacher Education	Computerized PD - teachers were randomly assigned to either a virtual workshop group that used a multimedia software program for PD or an actual workshop group that participated in a live PD session. In Study 1, the teachers' knowledge about the routine and planning for the routine significantly improved after completing either workshop; no significant differences were found between the groups. Both teacher groups were satisfied with the PD. In Study 2, the teachers' performance of the routine in their classrooms improved, as did student performance on tests of concept knowledge. Students were satisfied with the instruction provided by both groups of teachers. No differences were found between the posttest scores earned by the teacher groups or by students of the teachers.	Backward Hill 2013, EBSCOT	Yes
9	Brown, Faughn, Kent, & Tuba	No Year	Supporting Beginning Mathematics Teachers with Technology-based PD	Conference Paper (not sure)	CMP and other PD models-academic support and intensity of PD. We focus on the impact of technology-based professional development on beginning teachers' sense of empowerment, both in the classroom and in the broader mathematics education community. Four different models of professional development aimed at supporting teachers in their work while promoting TPACK (qualitative framework) acquisition. Our analysis shows that each model responded to various needs for the participants and brought them further in their development towards incorporating technology efficiently in the mathematics classroom in order to meet the TPACK Standards.	Google	Yes
10	Santagata and Angelici	2010	Studying the Impact of the Lesson Analysis Framework on Pre-service Teachers' Abilities to Reflect on Videos of Classroom Teaching	Journal of Teacher Education	Investigates the impact of an observation framework on pre-service teachers' abilities to engage in productive video-based reflections on mathematics teaching. Sixty-four 6th-grade teachers from five low-performing inner-city schools participated in the study and were randomly assigned to treatment and control groups. Measures included fidelity of implementation, teacher knowledge and practice, and student mathematics learning. The program did not impact significantly teacher knowledge or practices as measured in the study. An effect was found on mathematics learning for students whose teachers reached a certain level of mathematics content knowledge.	Backward Hill 2013, EBSCOT	Yes
11	Seidel, Sturmer, Blomberg, Kobarg, and Schwindt	2011	Teacher learning from analysis of Video classroom situations: Does it make a difference whether teachers observe their own teaching or that of others?	Teaching and Teacher Education	Experimental Approach-effects analyzing videos on one's own teaching versus others' teaching and experience with video has on teacher learning, particularly on knowledge activation and professional vision (N = 67). Teachers who analyzed their own teaching experienced higher activation, indicated by higher immersion, resonance, and motivation. Contrary to our assumptions differences with regard to professional vision were not straightforward. In tendency, teachers noticed more relevant components of teaching and learning but were less self-reflective with regard to articulating critical incidents.	Backward Hill 2013 EBSCOT,	Yes

12	Sherin, Han	2004	Teacher learning in the context of a Video Club	Teacher and Teacher Education	Video Club PD-the learning that occurs as 4 middle school teachers participate in 1 yr. The use of video clubs in which groups of teachers watch and discuss videotapes of their classrooms. Over time, discourse in the video clubs shifted from a primary focus on the teacher to increased attention to students' actions and ideas. In addition, discussions of student thinking moved from simple restatements of students' ideas to detailed analyses of student thinking. Furthermore, teachers began to reframe their discussions of pedagogical issues in terms of student thinking.	Backward-Hill 2013-EBSCOT	Yes
13	Sherin and Van Es	2009	Effects of Video club Participation on Teachers' Professional Vision	Journal of Teacher Education	Mathematics Teachers learning in a video-based PD for 2 years- called video clubs. Explore whether teachers develop professional vision, the ability to notice and interpret significant features of classroom interactions, as they participate in a video club. Participating in a video club was found to influence the teachers' professional vision as exhibited in the video club meetings, in interviews outside of the video club meetings, and in the teachers' instructional practices.	Backward Hill 2013, EBSCOT	Yes
14	Zhang, Lunderberg, Koehler, and Eberhardt	2011	Understanding affordances and Challenges of three types of video for teacher PD	Teacher and Teacher Education	Positive effects on teacher learning from observing published video, their own, their colleagues. We examined the affordances and challenges of the three types of video when they were used in a Problem-Based Learning pd program, drawing upon multiple data sources from 26 Ke12 science teachers. We present a case study to illustrate how one teacher might learn from each type of video, and conclude with recommendations for using video in pd.	Backward- Hill 2013-EBSCOT	Yes
15	Penuel, Fishman, Yamaguchi, and Gallagher	2007	What Makes PD Effective? Strategies That Foster Curriculum Implementation	American Educational Research	Science PD-different characteristics-A sample of 454 teachers engaged in an inquiry science program to examine the effects of different characteristics of pd on teachers' knowledge and their ability to implement the program. Results from a survey of teachers served by 28 pd providers within a hierarchical linear modeling framework. This study points to the significance of teachers perceptions about how coherent their pd experiences were for teacher learning and program implementation. The incorporation of time for teachers to plan for implementation and provision of technical support were significant for promoting program implementation in the program.	EBSCOT, ERIC	Yes

16	Garet, Porter, Desimone, Birman & Yoon	2001	What Makes PD Effective? Results from a National Sample of Teachers	American Educational Research Association	First Large Empirical comparison of effects of different characteristics PD-a national probability sample of 1,027 mathematics and science teachers to provide the first large-scale empirical comparison of effects of different characteristics of pd on teachers' learning. Results, based on ordinary least squares regression, indicate three core features of professional development activities that have significant, positive effects on teachers' self-reported increases in knowledge and skills and changes in classroom practice: (a) focus on content knowledge; (b) opportunities for active learning; and (c) coherence with other learning activities. It is primarily through these core features that the following structural features significantly affect teacher learning: (a) the form of the activity (e.g., workshop vs. study group); (b) collective participation of teachers from the same school, grade, or subject; and (c) the duration of the activity.	Google, EBSCOT	Yes
17	Hill, Ball	2004	Learning Mathematics for Teaching: Results from California's Mathematics PD Institutes	Journal for Research in Mathematics Education	Mathematics PD Institutes measuring teacher knowledge for teaching mathematics-gaps. We describe an effort to evaluate California's Mathematics Professional Development Institutes (MPDIs) using novel measures of knowledge for teaching mathematics. Our analyses showed that teachers participating in the MPDIs improved their performance on these measures during the extended summer workshop portion of their experience. This analysis also suggests that program length as measured in days in the summer workshop and workshop focus on mathematical analysis, reasoning, and communication predicted teachers' learning.	Google	Yes
18	McGatha, Bush, Rakes	2009	The Effects of PD in Formative Assessment on Mathematics Teaching Performance and Student Achievement	Assessment of Learning	1 yr PD program on formative assessment for MS teachers and its impact on teachers' use of formative assessment during instruction. The focus of the program was to support teachers in (a) embedding formative assessments into their instruction, (b) interpreting student responses and performance on formative assessments, (c) using effective questioning strategies and peer assessment, and (d) identifying student errors and misconceptions and implementing instructional strategies to address them. Teacher and student performance data were collected on participating teachers, control teachers, and their students during the year-long professional development. The pd had an impact on teachers' cognitive level of questioning, use of peer assessment, and types of questioning strategies. Results of student performance data revealed differences in performance on some types of items among students of participating teachers and control teachers.	Backward Hill 2013, EBSCOT	Yes

19	Heller, Daehler, Wong, Shinohara, and Miratrix	2012	Differential Effects of Three PD Models on Teacher Knowledge and Student Achievement in elementary Science	Journal of Research in Science Teaching	Casual inferences to link PD to teacher knowledge, practice, & student achievement-To identify links among professional development, teacher knowledge, practice, and student ach., researchers have called for study designs that allow causal inferences and that examine relationships among features of interventions and multiple outcomes. In a randomized experiment implemented in six states with over 270 elementary teachers and 7,000 students, this project compared three related but systematically varied teacher interventions—Teaching Cases, Looking at Student Work, and Metacognitive Analysis—along with no-treatment controls. Findings suggest investing in pd that integrates content learning with analysis of student learning and teaching rather than advanced content or teacher metacognition alone.	Backward Hill 2013, EBSCOT	Yes
20	Santagata, Kersting, and Stigler	2011	Problem Implementation as a Lever for Change: An Experimental Study of the Effects of a PD program on Students' Mathematics Learning	Journal of Research on Educational Effectiveness	Experimental Design-the effectiveness of a PD program on teacher knowledge and practices and on student learning. The program did not impact significantly teacher knowledge or practices as measured in the study. An effect was found on mathematics learning for students whose teachers reached a certain level of mathematics content knowledge. Discussion of findings includes lessons learned about conducting and studying pd, particularly in low-performing schools.	Backward Hill 2013, EBSCOT	Yes
21	Harris & Sass	2011	Teacher training, teacher quality and student achievement	Journal of Public Economics	Effects of various types of education and training on the productivity of teachers promoting student achieve. Our results suggest that only two of the forms of teacher training we study influence productivity. First, content-focused teacher professional development is positively associated with productivity in middle and high school math. Second, more experienced teachers appear more effective in teaching elementary math and reading and middle school math. There is no evidence that either pre-service (undergraduate) training or the scholastic aptitude of teachers influences their ability to increase student achievement.	ERIC	Yes

22	Cobb, Wood, Yackel, Nicholls, Wheatley, Trigatti, and Perlwitz	2001	Assessment of a Problem-Centered Second-grade Mathematics Project	Journal of Research in Mathematics Education	10 second grade classes-yr. long project comparison to a non socio-constructivist theory of knowledge. At the end of the school year, the 10 project classes were compared with 8 non-project classes on a standardized achievement test and on instruments designed to assess students' computational proficiency and conceptual development in arithmetic, their personal goals in mathematics, and their beliefs about reasons for success in mathematics. The levels of computational performance were comparable, but there were qualitative differences in arithmetical algorithms used by students in the two groups. Project students had higher levels of conceptual understanding in mathematics; held stronger beliefs about the importance of understanding and collaborating; and attributed less importance to conforming to the solution methods of others, competitiveness, and task-extrinsic reasons for success. Responses to a questionnaire on pedagogical beliefs indicated that the project teachers' beliefs were more compatible with a socio-constructivist perspective than were those of their non-project colleagues.	Backward Hill 2011, EBSCOT	Yes
23	Darling-Hammond, Wei, Andree, Richardson, and Orphanos	2009	Professional Learning in The Learning Profession: A Status Report on Teacher Development in the United States	National Staff Development Council	Effective PD-This report reveals that much of the pd available today focuses on educators' academic content knowledge, and pays growing attention to mentoring support, particularly for new teachers. But, overall, the kind of high-intensity, job-embedded collaborative learning that is most effective is not a common feature of pd across most states, districts, and schools in the United States. The purpose of this report is to provide policymakers, researchers, and school leaders with a teacher-development research base that can lead to powerful professional learning, instructional improvement, and student learning. It examines what research has revealed about professional learning that improves teachers' practice and student learning. It describes the relative availability of such opportunities in the United States as well as in high-achieving nations around the world, which have been making substantial and sustained investments in professional learning for teachers over the last two decades.	ERIC	Yes
24	Huffman & Thomas	2003	Relationship Between PD, Teachers, Instructional Practices, and the Achievement of Students in Science & Mathematics	School of Science and Mathematics	Examine the relationship between different types of pd, teachers' instructional practices, and the achievement of students in science and mathematics. Regression analysis-examine the relationship between different types of PD, teachers' instructional practices, and the ach. Of students in science and math. Regression analyses suggested that for both science and mathematics teachers, examining practice and curriculum development were significantly related to the use of standards-based instructional practices. Only curriculum development for mathematics teachers was significantly related to student achievement. Implications of results for the pd of science and mathematics teachers are discussed.	EBSCOT, TRC	Yes

25	Kennedy	1998	Form and Substance in Mathematics and Science PD	National Institute of Science Brief	Effect size- review studies of PD for teachers to examine students' benefits in math and science education. The review suggests that the differences among programs that mattered most were differences in the content that was actually provided to teachers, not difference in program forms or structures.	Backward Hill 2013 EBSCOT	Yes
26	Ross, Bruce, Hogaboam-Gray	2006	The Impact of a PD Program on Student Achievement in Grade 6 mathematics	Journal of Mathematics Teacher Ed.	Grade 6 teachers (N = 106) in one school district were randomly assigned to early or late professional development (PD) groups. The program focused on reform communication and incorporated principles of effective PD recommended by researchers, although the duration of the treatment was modest (one full day and four after school sessions over a ten-week period). At the post-test, there were no statistically significant differences in student achievement	ERIC (ProQuest)	Yes
27	Saxe, Gearhart, Nasir	2001	Enhancing Students Understanding of Mathematics: A Study of Three Contrasting Approaches to PD	Journal of Mathematics Education	Evidence of the influence of pd and curriculum on upper elementary students' understandings of fractions. Three groups of teachers and their students participated. Two groups implemented a fractions unit that emphasized problem solving and conceptual understanding. The Integrated Mathematics Assessment (IMA) group participated in a program designed to enhance teachers' understandings of fractions, students' thinking, and students' motivation. The Collegial Support (SUPP) group met regularly to discuss strategies for implementing the curriculum. Teachers in the third group (TRAD) valued and used textbooks and received no pd support. Contrasts of student adjusted posttest scores revealed group differences on two scales. On the conceptual scale, IMA classrooms achieved greater adjusted posttest scores than the other two groups, with no differences between SUPP and TRAD groups. On the computation scale, contrasts revealed no differences between IMA and TRAD, although TRAD achieved greater adjusted scores than SUPP ($p < 0.10$). Our findings indicate that the benefits of reform curriculum for students may depend upon integrated pd, one form exemplified by the IMA program.	Backward Hill 2011, EBSCOT	Yes
28	Jacob, Lefgren	2004	The Impact of Teacher Training on Student Achievement: Quasi-Experimental Design	The Journal of Human Resources	A regression discontinuity strategy to estimate the effect of teacher training on the math and reading performance of elementary students. We find that marginal increases in in-service training have no statistically or academically significant effect on either reading or math achievement, suggesting that modest investments in staff development may not be sufficient to increase the achievement of elementary school children in high-poverty schools.	PsycINFOr	Yes

29	Desimone, Porter, Garet, Yoon and Birman	2002	Effects of PD on Teacher's Instruction: Results from a three-year longitudinal study	American Journal Research Association	Examines the effects of professional development on teachers' instruction. Using a purposefully selected sample of about 207 teachers in 30 schools, in 10 districts in five states, we examine features of teachers' professional development and its effects on changing teaching practice in mathematics and science from 1996-1999. We found that pd focused on specific instructional practices increases teachers' use of those practices in the classroom. Furthermore, we found that specific features, such as active learning opportunities, increase the effect of the professional development on teacher's instruction.	ERIC, EBSCOT	Yes
30	Marra, Arbaugh, Lannin, Abell, Ehlert, Smith, Merle-Johnson, Rogers	2011	Orientations to PD Design and Implementation: Understanding their Relationship To PD Outcomes Across Multiple Projects	International Journal of Science and Mathematics Education	14 Science and Math PD projects and examine the relationship between project characteristics and outcomes (perceived improvement in teaching practices). . A PD orientation is comprised of project characteristics that drive the PD design and implementation for that project. The results provide support for the value of the framework and demonstrate that PD projects with different orientations exhibit differing participant outcomes.	Springer Link	Yes
31	Bell, Wilson, Higgins, McCoach	2010	Measuring the Effects of PD on Teacher Knowledge: The Case of Developing Mathematical Ideas	National Council of Teachers of Mathematics	Examine PD program (DMI) on teachers' specialized knowledge for teaching mathematics. Participants completing 2 DMI modules were compared with similar colleagues who had not taken DMI. Teacher knowledge was measured with multiple-choice items developed by the Learning Mathematics for Teaching project and open-ended items based on problems initially developed by DMI experts. After controlling for pretest scores, a hierarchical linear model identified statistically significant differences: The DMI group outperformed the comparison group on both assessments. Gains in teachers' scores on the more closely aligned measure were related to the degree of facilitator experience with DMI.	EBSCOT, ERIC, TRC	Yes
32	Blank & De las Alas	2009	Effects of Teacher PD on Gains in Student Achievement: How Meta-Analysis Provides Scientific Evidence Useful to Education Leaders	Council of Chief State School Officers	PD in relationship to Time, Activities, and Active learning Meta-Analysis of 16 studies. The analysis focused on completed studies of effects of pd for K-12 teachers of science and mathematics. The meta-analysis results show important cross-study evidence that teacher professional development in mathematics does have significant positive effects on student achievement. The analysis results also confirm the positive relationship to student outcomes of key characteristics of design of pd programs.	EBSCOT	
33	Hill and Ball	2005	Effects of Teachers' Mathematical Knowledge for Teaching on Student Achievement	American Educational Research Association	Correlations Teachers' preparation, experience, and mathematical knowledge for teaching and student gains. Explored whether and how teachers' mathematical knowledge for teaching contributes to gains in students' mathematics achievement. We used linear mixed model methodology in which first (n=1190) and third (n=1773) graders' mathematical achievement gains over a year were nested within teachers (n=334 and n=365), who in turn were nested within schools (n=115). We found teachers' mathematical knowledge was significantly	ERIC-(ProQuest)	Yes

					related to student achievement gains in both first and third grades, controlling for key student and teacher-level covariates.		
34	Telese	2012	Middle School Mathematics Teachers' PD and Student Achievement	The Journal of Educational Research	The Impact of MS mathematics teachers' content knowledge & student achievement-examined Grade 8 data from the 2005 National Association of Educational Progress math assessment. The purposes of the study were to (a) determine the impact of middle school mathematics teachers' content knowledge and teachers' mathematics pedagogical knowledge on student ach. and (b) compare the effect of the degree to which teachers received reform-oriented pd activities on student ach. The results indicated that mathematics content knowledge has a larger role in predicting student achievement than mathematics pedagogical knowledge. Also, teachers who reported participating in fewer pd activities had students with higher scores than those students whose teachers reported either participating in more pd. Regression was used.	EBSCOT	Yes
35	Yoon, Duncan, Wen-Yu Lee, Scarloss, and Shapley	2007	Reviewing the Evidence on how teacher PD affects student achievement	Institute of Education Sciences US Department of Education	Meta-Analysis of the more than 1,300 studies identified as potentially addressing the effect of teacher professional development on student achievement in three key content areas, nine meet What Works Clearinghouse evidence standards, attesting to the paucity of rigorous studies that directly examine this link. This report finds that teachers who receive substantial professional development—an average of 49 hours in the nine studies—can boost their students' achievement by about 21 percentile points.	Google, ERIC	Yes
36	Heller, Curtis, Rabe-Hesketh, Clarke, & Verbencoeur	2007	The Effects of "Math Pathways and Pitfalls" on student mathematics Ach.	National Science Foundation Final Report	Cluster-Random experimental Design-Math Pathways and Pit-Falls (MPP) impact on second-, fourth-, and sixth-grade student grade teachers-pedagogical skills. Student math performance in MPP classes was higher than in non-MPP classes for all three grade levels. There were no differences between the effectiveness of MPP for students with mathematically stronger versus weaker entering knowledge except at fourth grade, where MPP was more effective for children who had higher pretest scores. On standardized mathematics tests, for the fourth and sixth-grade students, no statistically significant difference was found between the means of control and experimental group students. (No analysis was performed for the second-grade students because standardized-test-score data were not available.)The positive impact of MPP on student mathematics performance, as measured by the MPP Pitfalls Quizzes, is consistent with results of an earlier pilot study of MPP materials by Heller, Gordon, Paulukonis, and Kaskowitz (2000). Because the current study was based on a more rigorous research design (i.e., a cluster randomized design) than the one used in the Heller et al. pilot study, the results of the current study can be viewed as even stronger evidence of the effectiveness of the MPP materials.	ERIC	Yes

37	Creemers, Kyriakides, and Antoniou	2013	An Experimental Study of Teacher Professional Development Based on the Dynamic Integrated Approach	Teacher Professional Development for Improving Quality of Teaching (Book)	Experimental Study on how teachers can develop their skills using DIA intervention-teaching skills and student outcomes mean, sd, t test. The results of the analysis of both the initial and final data related to teaching skills suggest that the five stages of teaching skills were formulated in a consistent manner. This provides support for the generalizability of the five developmental stages of teaching skills proposed by previous research findings (Antoniou et al., 2009). In addition, it was found that teachers demonstrating higher level competencies were more effective than those situated at the lower stages in terms of student outcomes. Secondly, the results indicated that for all teachers, the DIA is more effective than the HA in improving teaching skills. By comparing the two experimental groups, it was found that, overall, teachers employing the HA neither made statistically significant progress nor moved from one stage to another. On the other, hand, statistically significant progress in teaching skills was found for the teachers employing the approach based on the grouping of teaching skills in the dynamic model. Thirdly, it was found that employing the DIA had a reasonable and statistically significant effect on student achievement, compared with employing the HA.	Google	Yes
38	Blank, Smithson, Porter, Nunnaley, and Osthoff	2006	Improving Instruction through Schoolwide PD: Effects of the Data-on-Enacted-Curriculum Model	ERS Spectrum	The instructional improvement model data on Enacted Curriculum was tested with an experimental design using randomized place-based trials. Tested in 50 US schools. The longitudinal analysis of instruction before and after treatment showed math teachers in treatment schools had significant improvement in alignment of instruction with standards compared with teachers in control schools, and the math teachers on the leader teams showed significantly greater gains than all other teachers	EBSCOT	Yes
39	McMeeking, Orsi, and Cobb	2012	Effects of a Teacher PD Program on the Mathematics Achievement of Middle School Students	National Council of Teachers of Mathematics (NCTM)	15 to 24 month in-service PD using a quasi-experimental design. Results showed that students' odds of achieving a score of proficient or better increased with teacher participation in the PD program	EBSCOT, ERIC, TRC	Yes
40	Casa, Tinto	2005	Viewing Professional Development Through Different Lenses: Experiences of Two Major Grant Projects	Conference-Proceedings of the 27th annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education.	Ten Schools of varying socioeconomics levels in CT and KY are participating. Teachers take part in an intensive two week summer session, Pd in-services during the year-aimed to increase student achievement.	EBSCOT	Yes-Poster-not enough inform.
41	Bruce, Esmonde, Ross, Dookie, and Beatty	2010	The effects of sustained classroom-embedded teacher professional learning on teacher efficacy and related student achievement	Teacher and Teacher Education	The impact of a classroom-embedded professional learning (PL) program for mathematics teaching in two contrasting districts in Canada, and investigates the relationship between teacher efficacy and student achievement. Before the PL, District A had lower teacher efficacy and student achievement than District B, but after the PL, this situation was reversed. Qualitative analysis revealed that the two districts reported learning very different things from the PL opportunity. The complexities of context, prior learning experiences, goal setting, and persistence of participants all factored into what and how teachers learned.	EBSCOT	Yes/NA

42	Hristovitch & Mitcheltree	2004	Exploring MS Teachers Pedagogical Content Knowledge of Fractions and	Conference-Psychology of Mathematics and Education of North America Annual Meeting	Conference-The findings suggest that the activities of a pd program addressing teachers' pedagogical content knowledge should focus on enhancing teachers' ability to connect math ideas.	EBSCOT	Yes-inc. no email response
43	OECD	2009	The professional development for teachers	Book-chapter 3	Report	EBSCOT	Yes
44	Zwiep & Benken	2012	Exploring Teachers' Knowledge and Perceptions Across Mathematics and Science Through Content-Rich Learning Experiences in a PD Setting	International Journal of Science &	Large PD program long term components-Knowledge of content and perceptions of areas: findings indicate that although teachers involved in both math and science can benefit from similar overall PD structures-leads to teaching learning and change.	EBSCOT	Yes
45	Cave & Brown	2010	When Learning Stakes: Exploration of Role of Teacher Training and PD Schools Elementary Students' Math Achieve	National Forum of Teacher Education Journal	Explore how a PD (PDS) collaboration project contributed to improved elementary students' math achieve in an Urban setting.	EBSCOT	Yes
46	Graham	2007	Improving Teacher Effectiveness through Structured Collaboration: A Case Study of a Professional Learning Community		Professional learning community activities-that comprise same subject same grade teacher teams-had a improvements in teaching effectiveness, but effectiveness depend on a number of factors.	EBSCOT	Yes
47	Owston, Sinclair, & Wideman	2008	Blended Learning For Professional Development: An Evaluation Of A Program For Middle School Mathematics And Science Teachers.	Teacher Record (1970)	An evaluation of a two-year professional development project for mathematics and science teachers in grades 6, 7, and 8 that blended face-to-face workshops with online sessions. Data were obtained using a pre-post design that included surveys, classroom observations, and key informant interviews.	EBSCOT, PsycINFO, TRC	Yes
48	Kleickmann, Richter, Kunter, Elsner, Besser, Krauss, and Baumert	2013	Teachers' Content Knowledge and Pedagogical Content Knowledge: The Role of Structural Differences in Teacher Education	Journal of Teacher Education	We compared the PCK and CK of four groups of mathematics teachers at different points in their teaching careers in Germany. Confirmatory factor analyses showed that PCK and CK measurement was satisfactorily invariant across the teacher populations considered. As expected, the largest differences in CK and PCK were found between the beginning and the end of initial teacher education. Differences in the structures of teacher education were reasonably well reflected in participants' CK and PCK.	ERIC-(ProQuest)	Yes
49	Scher & O'Reilly	2009	Professional Development for K–12 Math and	Journal of Research on Educational Effectiveness	This article summarizes the current knowledge-base and offers a theoretical framework researchers can use to design studies that explore mechanisms through which professional development programs influence teacher knowledge, teacher practices, and ultimately student achievement.	EBSCOT	Yes

50	Dash, De Kramer, O'Dwyer and Masters	2012	Impact of Online Professional Development on Teacher Quality and Student Achievement in Fifth Grade Mathematics	Journal of Research on Technology in Education (International Society for Technology in Education)	This manuscript presents findings from an impact study of OPD courses in fractions, algebraic thinking, and measurement on 79 fifth grade teachers' pedagogical content knowledge and pedagogical practices as well as their students' mathematics achievement. The research findings showed that teachers who had been randomly assigned to the experimental group had significantly greater gains in scores for pedagogical content knowledge and pedagogical practices than teachers in the control group. Nevertheless, the positive changes in teacher outcomes did not translate to any meaningful differences in students' mathematics achievement.	ERIC, TRC	Ye
51	Smith, Desimone and Ueno	2005	"Highly Qualified" to Do What? The Relationship between NCLB Teacher Quality Mandates and the Use of Reform-Oriented Instruction in Middle School Mathematics	American Educational Research Association	The authors examine the relationships among educational credentials, preparedness to teach content, participation in professional development, and use of reform-oriented instruction by middle school mathematics teachers using data from the 2000 National Assessment of Educational Progress (NAEP). Their analyses suggest that preparedness to teach mathematics content and participation in content-related professional development activities are associated with reform-oriented teaching, measured here as increased emphases on conceptual learning goals for students and increased use of reform-oriented teaching strategies.	ERIC	YES
52	Thornton, Crim, and Hawkins	2009	The Impact of an Ongoing Professional Development Program on Prekindergarten Teachers' Mathematics Practices	Journal of Early Childhood Teacher Education	An ongoing professional development program, specifically targeting teachers of prekindergarten children in public school, Preschool Programs for Children with Disabilities (PPCD), Head Start, and child care settings, teachers reported positive changes in math practices. Implications from this study suggest that ongoing pd that is designed to meet the specific needs of early childhood educators can have a positive impact on reported mathematics content knowledge and instructional practices.	EBSCOT	Yes
53	Bailey	2010	The Impact of Sustained, Standards-Based Professional Learning on Second and Third Grade Teachers' Content and Pedagogical Knowledge in Integrated Mathematics	Early Childhood Education	This 3 year longitudinal study reports the feasibility of an Improving Teacher Quality: No Child Left Behind project for impacting teachers' content and pedagogical knowledge in mathematics in nine Title I elementary schools in the southeastern United States. The implementation of standards-based methods in the nine Title I Schools increased teacher quality in elementary school mathematics. In fact, qualitative and quantitative data revealed significant gains in teachers' mathematics content and pedagogical knowledge at both grade levels.	ERIC	Yes
54	Harrisa, Stevens and Higgins	2011	A Professional Development Model for Middle School Teachers of Mathematics	International journal of mathematical education in science and technology	In this article, we describe a professional development model that strives to provide middle school mathematics teachers with a deep understanding of the mathematics they teach, and our attempts to measure its influence on their mathematics content knowledge.	ERIC	Yes

55	Telese	2012	Middle School Mathematics Teachers' Professional Development and Student Achievement	The Journal of educational research (Washington, D.C.)	The purposes of the study were to (a) determine the impact of middle school mathematics teachers' content knowledge and teachers' mathematics pedagogical knowledge on student achievement and (b) compare the effect of the degree to which teachers received reform-oriented pd activities on student achievement. The results indicated that mathematics content knowledge has a larger role in predicting student achievement than mathematics pedagogical knowledge.	EBSCOT, ERIC, PsycINFO	YES
56	Carey, Kleiman, Russell, Venable, & Louie	2008	Online Courses for Math Teachers: Comparing Self-Paced and Facilitated Cohort Approaches	The Journal of Technology, Learning, and Assessment	This study investigated whether two different versions of an online professional development course produced different impacts on the intended outcomes of the course. One was an actively facilitated course with asynchronous peer interactions among participants. The second was a self-paced condition, in which neither active facilitation nor peer interactions were available. Both conditions showed significant impact on teachers' mathematical understanding, pedagogical beliefs, and instructional practices. Surprisingly, the positive outcomes were comparable for both conditions.	ERIC	Yes
57	Alvarez	2008	The Relationship of teacher quality and student achievement in Elementary Schools from the New Year City.	Dissertation	The present study sought to examine the relationship between teacher quality and student achievement in public elementary schools in a community district school of the New York City. It has 23 elementary schools, more than 7,600 students and around 350 teachers. This study confirms that teachers' professional development components such as participation in professional development activities, support received, rewards gained and collaboration activities are statistically related to the student achievement in Math and ELA test.	ERIC (ProQuest)	Yes
58	Polly, Wang, McGee, Lambert, Martin, and David Pugalee	2014	Examining the Influence of a Curriculum-Based Elementary Mathematics Professional Development Program	Journal of Research in Childhood Education	This study presents findings from the first cohort of teachers in a U.S. Department of Education Mathematics Science Partnership (MSP) grant designed to support the use of a standards-based elementary school mathematics curriculum, Investigations in Number, Data, and Space (Investigations). In line with the goals of the MSP program, the 84-hour professional development program focused on building teachers' knowledge of mathematics content, examining how the mathematics content is embedded into curriculum, and supporting teachers' enactment of reform-based pedagogies.	EBSCOT	YES
59	Polly, Neale, & Pugalee	2014	How Does Ongoing Task-Focused Mathematics Professional Development Influence Elementary School Teachers' Knowledge, Beliefs and Enacted Pedagogies?	Early Childhood Education Journal	This study examined how a task-focused, year-long mathematics professional development program influenced elementary school teachers' knowledge, beliefs, and practices. Three teacher-participants were randomly selected to be observed 3 times over the course of the school year. Data analyses indicated that the pd had a statistically significant positive impact on participants' mathematical knowledge for teaching, use of student-centered instructional practices, and beliefs towards mathematics as a subject area.	EBSCOT	YES

60	Campbell, Nishio, Smith, Clark, Conant, Rust, DePiper, Frank, Griffin and Choi	2014	The Relationship Between Teachers' Mathematical Content and Pedagogical Knowledge, Teachers' Perceptions, and Student Achievement	Journal for Research in Mathematics Education	Mathematical content and pedagogical knowledge of middle-grades teachers were each directly and positively related to their students' mathematics achievement, with and without teacher-level controls. Significant interactions emerged between teachers' perceptions and knowledge influencing student achievement.	TRC	Yes
61	Desimone, Smith and Phillips	2013	Linking Student Achievement Growth to PD Participation and Changes in Instruction: A Longitudinal Study of Elementary Students and Teachers in Title I Schools	Journal: Teachers College record (1970)	To what extent do teachers' topic coverage, emphasis on memorization and solving novel problems, and time spent on mathematics instruction, predict student mathematics achievement growth? (2) To what extent does teacher participation in content-focused professional development predict the aspects of instruction found in our first analysis to be related to increases in student mathematics achievement growth? When teachers participated in professional development that focused on math content or instructional strategies in mathematics (in Year 1), they were more likely to teach in ways associated with student achievement growth.	TRC, PsycINFO	Yes
62	Krawec and Montague	2014	The Role of Teacher Training in Cognitive Strategy Instruction to Improve Math Problem Solving	Learning Disabilities Research & Practice,	The purpose of this article is to offer teacher training and professional development recommendations in mathematics based on the findings of a federally funded 3-year intervention study that improved the problem solving of middle school students with a focus on students with learning disabilities. Over the 3-year project, 29 seventh and eighth grade teachers implemented a problem-solving intervention based on cognitive strategy instruction. Though the intervention was successful in improving students' problem-solving performance, several issues related to teaching effectiveness and teacher training came to light. The article will: (1) describe the intervention and its implementation, (2) present the findings of the study, and (3) discuss the issues of effectiveness and possible solutions via teacher education and professional development	PsycINFO	Yes
63	Broyles	2009	The effect of teacher participation in the gateway institute of algebra on student academic achievement.	Dissertation	The purpose of this study was to relate a teacher's participation in the Gateway Institute for Algebra, a professional development activity that was designed and delivered by the Tennessee Department of Education each summer, to student performance on the Math Foundations II end-of-course exam and the Algebra Gateway exam for students in four high schools in a large school district in West Tennessee. Multivariate Analysis of Covariance (MANCOVA) was used to analyze data collected from the High School Mathematics.	ProQuest	Yes

64	Patrick	2014	A meta-analysis of dissertation research on the relationship between professional learning community implementation and student achievement.	Dissertation	The purpose of this study was to conduct a meta-analysis of dissertation research that examined the implementation of professional learning communities (PLCs) and student achievement in preK-12 schools. Results indicated that Shared and Supportive Leadership, Shared Vision, and relational factors of Supportive Conditions were influential in these analyses. Although the hypothesis that PLC implementation significantly increases math achievement was not supported, the hypothesis that PLC implementation significantly increases reading achievement was partially supported.	PsycINFO	Yes
65	Spiller		The relationship among professional learning communities, a response to intervention framework and mathematics scores in middle and high schools	Dissertation	The purpose of this study was to determine the relationship between professional learning community (PLC) factors, components of an implementation of response to intervention (RTI) and student learning in mathematics at the middle and high school level. Results indicated a possible relationship between factors on the SPSLCQ and RTI dimensions. An analysis of a PLCs link to student learning showed no relationship; however, a relationship between aspects of an RTI process at Tier 1 and student increases in math score was noted.	PsycINFO	Yes
66	Allen	2012	The Impact of Professional Learning Communities on Third-Grade Math Scores	Dissertation	This study examined whether or not teacher collaboration in professional learning communities, which is a form of professional development, affected student learning in third-grade mathematics. The sample for the study consisted of 120 students (i.e., 60 students for the experimental group and 60 students for the control group). Professional learning communities can be incorporated in the school improvement plan to address the math proficiency of the school community, as well as provide professional development among the teachers that affect student learning.	PsycINFO	YES
67	Roher	2012	The relationship between the degree of participation in Online Embedded Professional Development communities for high school mathematics teachers and student achievement gains in College Algebra.	Dissertation	This correlation study examines the relationship between participation in online embedded professional development communities and student achievement gains in a College Algebra course taught by high school teachers to high school students for college credit. The study results indicated that as the amount of instructional time increases, there is a positive relationship to student achievement gains. There was not a significant relationship between student characteristics and student achievement gains. The results of this study indicates that when teachers are actively learning new instructional strategies with new embedded mathematical content in a Professional Learning Community, there is a positive relationship to student achievement gains.	PsycINFO	Yes

68	Wimberley	2013	Teacher collaboration and student achievement.	Dissertation	This study was conducted to explore the relationship between teacher collaboration and student achievement. The pedagogical model espoused by Howland and Picciotto (2003b) defined teacher collaboration as a pedagogy that involves two or more teachers who regularly discuss teaching and learning, including learning activities, lesson plans, assignments, pacing, course design, evaluating, and revising the program. Eighth grade student achievement scores in Communication Arts and Math from the 2009-2010 Missouri Assessment Program (MAP) were analyzed to determine the relationship between collaborative school districts and non-collaborative school districts. Through the application of a t-test, a significant relationship was found between school districts utilizing contracted time for teacher collaboration and higher student achievement. Findings from the study should be useful in informing educators regarding the potential impact of utilizing contracted time for teacher collaboration.	PsycINFO	Yes
69	Baumert, Kunter, Blum, Brunner, Voss, Jordan, Krass, Neubrand, and Tsai	2010	Teachers' Mathematical Knowledge, Cognitive Activation in the Classroom, and Student Progress	American Educational Research Journal	This article investigates the significance of teachers' content knowledge and pedagogical content knowledge for high-quality instruction and student progress in secondary-level mathematics. It reports findings from a 1-year study conducted in Germany with a representative sample of Grade 10 classes and their mathematics teachers. Teachers' pedagogical content knowledge was theoretically and empirically distinguishable from their content knowledge. Multilevel structural equation models revealed a substantial positive effect of pedagogical content knowledge on students' learning gains that was mediated by the provision of cognitive activation and individual learning support	PsycINFO	Yes
70	Erskine	2010	Raising mathematical achievement starts with the elementary teacher: Recommendations to improve content and pedagogical knowledge of elementary math teachers	Dissertation	This study attempts to explain the substantial differences in mathematical achievement of elementary students in a Delaware school district by analyzing the level of content and pedagogical knowledge of elementary math teachers. The results revealed, however, that many elementary teachers lack this necessary knowledge to support student learning in mathematics. Many teachers struggle with mathematics and fail to develop appropriate instructional strategies to support struggling learners. Those teachers with a strong content knowledge for teaching tended to have higher student achievement ($r = 0.614$). To raise other students to these higher levels of achievement.	PsycINFO	Yes

71	Walters	2009	Understanding and teaching rational numbers: A critical case study of middle school professional development.	Dissertation	This study focuses on the extent to which middle school mathematics teachers comprehended and made use of the core content, pedagogical content and pedagogical components of a well-designed professional development model. Teachers' understanding of math content is a critical link in the theory of action driving current educational policies that call for increased rigor and coherence in K-12 mathematics. This case study illustrates that even well designed and well implemented professional development models may be incapable of improving teachers' content knowledge to levels that positively affect their instructional practices.	PsycINFO	Yes
72	Lesar	2014	The relationship between grade-level team implementation of professional learning communities and student achievement in math.	Dissertation-Mixed Method	The study employed a multi-method, correlational, descriptive, non-experimental research design. Quantitative data were collected through teacher completion of a professional learning community (PLC) questionnaire and the Arizona Instrument to Measure Standards (AIMS) math assessment. The Professional Learning Communities Assessment-Revised (PLCA-R) questionnaire enabled teachers to report the extent to which they engage in practices known to support the development of a well-functioning PLC. This study determined the correlation between grade-level team overall implementation of PLCs measured by teacher completion of the PLCA-R questionnaire and student achievement of fourth-grade students measured by the AIMS math assessment.	PsycINFO	Yes
73	Jones and Gulek	2010	Characteristics of High-Quality Teachers	ERS Spectrum	Examine the characteristics of high-quality teachers who used a structured mathematics program for teaching (Math Achievement Program-MAPD)-A convenient sampling of 448 4th an 5th grade teachers-this program demonstrated significant students gains on the California's Standards test (CTS).	ERIC, PsycINFO	Yes
74	Benken and Brown	2004	Improving Students' Mathematical Understandings: An Exploration Into Teacher Learning In An Urban Professional Development Setting	Conference-Proceedings of the 27th annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education.	Examination of teacher learning within a pd experience for elementary mathematics teachers in urban charter schools aims to continue the conversation about supporting teachers in their efforts to teach mathematics in conceptually based ways. This work extends this underdeveloped area of research in two substantial ways: (1) in our effort we have implemented recommended facets of pd through the lens of content and pedagogy, and (2) we have situated this work in an underrepresented context (urban, charter school).	EBSCOT	No-email address no longer works 1-14-15
75	McGehee	2005	The Coaching/Mentoring Phase In A Professional Development Partnership Project	Conference-Proceedings of the 27th annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education.	The Professional Development and Curriculum Alignment project (PDCA) is an implementation research study that examines the ways in which the development of teacher mathematical knowledge and instructional practice links to student performance in mathematics.	EBSCOT	N0

76	Meyer and Wilkerson	2007	Lesson Study: The Effects On Teachers and Students In Urban Schools In The United States	Conference-Proceedings of the 27th annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education.	The focus of this poster session will be to share a professional development model of Lesson Study adapted from education experts such as Lewis (2002), Germain-McCarthy (2001), and Yoshida (1999). This research sought to examine the effects lesson study had on mathematics teachers and students in an urban middle school. In particular what effects lesson study had on teachers' instructional strategies and conceptual understanding as well as students' achievement and conceptual understanding was investigated?	EBSCOT	No-req. 1-14-15
77	Poetzl	2005	Developing Teacher Practice Through Video Analysis	Conference-Proceedings of the 27th annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education.	This pilot study takes place in an ongoing pd program in which teachers are studying their at risk student problem solving. The goal of the pd program is to develop interventions to help support the mathematics problem solving abilities of at risk students.	EBSCOT	No-email address no longer works req. 1-14-15
78	Siegfried, Gordon, and Garcia	2007	Barley In S.T.E.P: How Professional Development Affects Teachers Perspectives and Analysis of Student Work	Conference-Proceedings of the 29th annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education.	The purpose of this study is to determine how pd affects teachers' perspectives on and analysis of student work. To achieve this purpose, this study examines, analyzes, and scores responses from four groups of teachers with varying levels of pd experiences. The results suggest pd positively influence teachers' interpretation understanding, and assessment of student work.	EBSCOT	No-email address no longer works req. 1-14-15
79	Feuerborn, Chinn, and Morlan	2009	Improving mathematics teachers' content knowledge via brief in-service: a US case study	Professional Development in Education	This study is an evaluation on whether middle-level mathematics teachers' participation in a week-long in-service course on middle-level mathematics concepts increases their understanding of this content. A secondary purpose of this study is an exploration of teacher perceptions before and after the institute via self-report surveys. The findings indicate that teachers' content knowledge significantly improved, as measured by pretest and post-test results.	EBSCOT	Yes
80	Van Haneghah, Pruit, Bambert	2009	Mathematics reform in a minority community: Student outcomes	Early Childhood Educational Journal	This 3 year longitudinal study reports the feasibility of an Improving Teacher Quality: No Child Left Behind project for impacting teachers' content and pedagogical knowledge in mathematics in nine Title I elementary schools in the southeastern United States. Data were collected for 3 years to determine the impact of standards and research-based teacher training on these aspects of teacher quality. The implementation of standards-based methods in the nine Title I Schools increased teacher quality in elementary school mathematics. In fact, qualitative and quantitative data revealed significant gains in teachers' mathematics content and pedagogical knowledge at both grade levels.	ERIC	Yes

81	DiNardo	2010	The Impact of Professional Learning Communities on Student Achievement	Dissertation	3rd and 5th grade. Professional learning communities (PLC) are one strategy aimed at facilitating teacher professional development, with a focus on increasing student achievement. This mixed methods study investigated the impact of professional learning on student achievement. Teachers in this study engaged in professional learning sessions focused on improving reading fluency and math instruction based on the conceptual framework of PLC application synthesized by Paratore. Two assessments were used to monitor student achievement. The outcomes of the study revealed significant increases in student achievement after professional learning sessions and the importance of properly implementing strategies learned. This study contributes to positive social exchange by helping to inform the professional development programs for teachers based on empirically tested interventions that support demonstrable changes in student learning.	ERIC	Yes
82	Krupa	2011	Evaluating the Impact of Professional Development and Curricula Implementation on Student Mathematics Achievement: A Mixed Methods Study	Dissertation	This study was designed to investigate the effects of an integrated reform-based curriculum, Core-Plus, on student learning on statewide End of Course exams (EOC-Algebra I and II) and to contextualize these outcomes in a state-funded professional development program with the elements of a summer program, follow-up workshops, and monthly site based support with instructional coaches. The study was also designed to compare and contrast major sub-groups: teachers using Core-Plus who did or did not participate in different elements of the professional development. Findings from this study indicate that North Carolina students enrolled in integrated mathematics outperformed subject-specific students on the Algebra I End-of-Course exam, which was highly aligned with content in Core-Plus textbook, and performed no differently on the Algebra II exam, which was not aligned with the Core-Plus materials.	ProQuest	Yes
83	Kuchey, Morrison, Geer	2009	A Professional Development Model for Math and Science Educators in Catholic Elementary Schools: Challenges and Changes	Journal of Educational Research	The purpose of the study was to examine the degree to which the Initiative for Catholic Schools (ICS), a 2-year professional development program for science and math teachers, demonstrated positive outcomes within the context of Catholic elementary education across the five levels of impact for a professional development program: participants 'reactions, participants ' learning, organization support and change, participants ' use of new knowledge and skills, and student learning outcomes. The results provide evidence of positive outcomes in the participants 'reactions, participants 'learning, organization support and change, and participants' use of new knowledge and skills. The impact on student learning outcomes was less consistent and varied by grade level.	Ebscot	Yes

84	Phelan, Choi, Vendlinski, Baker & Herman	2011	Differential Improvement in Student Understanding of Mathematical Principles Following Formative Assessment Intervention	Catholic Education: A Journal of Inquiry and Practice	A middle school mathematics formative assessment strategy. A randomized, controlled design to address the following question: Does using our strategy improve student performance on assessments of key mathematical ideas relative to a comparison group? 85 teachers and 4,091 students were included. Students took a pretest and a transfer measure at the end of the year. Treatment students completed formative assessments. Treatment teachers had exposure to professional development and instructional resources. Results indicated students with higher pretest scores benefited more from the treatment compared to students with lower pretest scores. In addition treatment students significantly outperformed control students on distributive property items. This effect was larger as pretest scores increased.	Ebscot	Yes

There are 83 studies →studies 34 and 55 are the same study (duplicates)

Appendix D-Criteria for Inclusion (83 Studies)

Paper	Authors	Year	Year	Math	CK	PCK	Publish/ UNP	PD Type	Control Group	Data-Sample, Mean, & SD	Qualified-X
1	Patel, Franco, Miura, and Boyd	2012	X	X	X	X	P	Content Focus PD	Pre-Post workshop assessment for teachers CK, PCK	N, M, SD, T-Test, Z scores, P values	X
2	Desimone, Smith, &Ueo	2006	X	X			P	Not PD			Not PD
3	Jacobs, Koellner, and Funderburk	2012	X	X			P	Problem Cycle PD			Data not available
4	O'Dwyer, Masters, Dash, DeKramer, Humez and Russell	2010	X	X	X	X	P	On line PD	Treatment/Control Group Teacher/Students	SD, M, ES, Ancova T	X
5	Russell, Kleiman, Carey, and Douglas	2009	X	X	X	X	P	Cohort-based On line course	PRE-Post Teacher CK, PCK	N, M, SD, ES	X
6	Fishman, Konstantopoulos, Kubitskey, Vath, Park, Johnson, and Edelson	2013	X	No			P	On line PD Curriculum			Not Math-Science
7	Russell, Carey, Kleiman, and Venable	2009	X	X	X	X	P	Same course On line PD/Face to Face	Pre-Post Treatment Group	N, M,	X
8	Fisher, Schumaker, Culbertson, & Deshler	2010	X	No			P				Not Math-Science
9	Brown, Faughn, Kent, & Tuba		X	X			P	Technology PD			Mixed Methods-Insufficient data
10	Santagata and Angelici	2010	X	X			P	Video PD			Pre-service Teachers
11	Seidel, Sturmer, Blomberg, Kobarg, and Schwindt	2011	X	No			P	Video PD			Not Math-Science
12	Sherin, Han	2004	X	X			P	Video PD		N, No mean, No SD	Insufficient Data
13	Sherin and Van Es	2009	X	X		X	P	Video PD	Pre-Post Teacher	N, M, SD,	X

14	Zhang, Lunderberg, Koehler, and Eberhardt	2011	X	No			P	Video PD			Not Math-Science
15	Penuel, Fishman, Yamaguchi, and Gallagher	2007	X	No			P	Curriculum PD			Not Math-Science
16	Garet, Porter, Desimone, Birman & Yoon	2001	No	X			p				Too old-out dated
17	Hill, Ball	2004	X	X	X		P	California's Math PD CK	Teachers Pre-Post test	N, M, SD, β HLM, Anova	X
18	McGatha, Bush, Rakes	2009	X	X	X	X	P	PD Formative Assessment	Teachers Pre-Post test, Control Group, Stud Ach	Teacher ES,STD. Mean, df, T test, F,	X
19	Heller, Daehler, Wong, Shinohara, and Miratrix	2012	X	No			P	3 Different PD's			Science and English
20	Santagata, Kersting, and Stigler	2011	X	X	X	X	P	PD Teachers' CK, PCK	Treatment/Control Group Teacher/Students	N, M, SD, T, W, ES, β,	X
21	Harris & Sass	2011	X	X			P	Not PD-Primary and Secondary Education			Not PD-training for per-service Teachers
22	Cobb, Wood, Yackel, Nicholls, Wheatley, Trigatti, and Perlwitz	2001	No	X			P	Problem Centered PD			Too old-out dated
23	Darling-Hammond, Wei, Andree, Richardson, and Orphanos	2009	X	X			P	Professional Learning PD			Insufficient Data
24	Huffman & Thomas	2003	X	X		X	P	Instructional Practice PD	Regression Duration, curriculum, and instruction, student learning	N, M, R^2, β	X
25	Kennedy	1999	No	X			P	Math and Science PD			Too old-out dated
26	Ross, Bruce, Hogaboam-Gray	2006	X	X	X	X	P	Impact Pd on Student 6th grade	Treatment Group, Pre-post test	N, M, SD, T, ES, F	X
27	Saxe, Gearhart, Nasir	2001	No	X			P		Pre-post, Treatment Group	N, M, SD, T, ES	Too old-out dated
28	Jacob, Lefgren	2004	X	X			P	The Impact of teacher training on Stud Ach	Quasi-experimental design		Not PD

29	Desimone, Porter, Garet, Yoon and Birman	2002	No	X			P	Math Instruction PD			Too old-out dated
30	Marra, Arbaugh, Lannin, Abell, Ehlert, Smith, Merle-Johnson, Rogers	2011	X	X	X	X	P	Factors that Impact Multiple PD		N, M, SE, F	X
31	Bell, Wilson, Higgins, McCoach	2010	X	X	X	X	P	Effect PD on Teachers' Knowledge	Pre-post, Treatment Group	N, M, SD, ES	X
32	Blank & De las Alas	2009	X	X	X	X	P	Meta-Analysis			Insufficient Data
33	Hill and Ball	2005	X	X	X		P	Teacher CK on St. Ach. Not PD			Not PD
34	Telese	2012	X	X	X	X	P	MS reform PD CK and PK on Stud Ach 8 NAEP	Teacher randomly selected of students	N, R^2, SE, M, SD, T, ES	X
35	Yoon, Duncan, Wen-Yu Lee, Scarloss, and Shapley	2007	X	X			P	Meta-Analysis 9 Studies on PD			Not PD Insufficient data
36	Heller, Curtis, Rabe-Hesketh, Clarke, & Verbencoeur	2007	X	X	X	X	P	Impact Math Pathways and Pitfalls (MPP) Curriculum based on 2nd, 4th, 6th grade students	Teacher and Students Pre-post, cluster randomization, Treatment group/control	N, M, SD,	X
37	Creemers, Kyriakides, and Antoniou	2013	X	X	X		P	Intergraded PD based on DIA-at University	DIA vs HA-teacher and students	N, M, SD, T, ES	X
38	Blank, Smithson, Porter, Nunnaley, and Osthoff	2006	X	X			P	Curriculum PD			Insufficient Data-No data
39	McMeeking, Orsi, and Cobb	2012	X	X	X	X	P	CK and PCK summer workshops and follow up experience.	2 cohorts of student measures cohorts of teachers. Teacher treatment and control	N, SD, log odds, odd ratios	X
40	Casa, Tinto	2005	X	X			UNP	Curriculum PD			Insufficient Data-conference paper
41	Bruce, Esmonde, Ross, Dookie, and Beatty	2010	X	X			P	Sustained PD On Teacher Efficacy and Stud. Ach			Sustained PD On Teacher Efficacy-not Ck and PCK

42	Hristovitch & Mitcheltree	2004	X	X			UNP	Pedagogical Content PD			Insufficient Data-conference paper
43	OECD	2009	X	No			P	PD for Teachers			Insufficient Data
44	Zwiep & Benken	2012	X	X	X		P	PD for Math and Science content	Pre-Post Student and Teachers	N, M, SD, Delta mean	X
45	Cave & Brown	2010	X	X			P	Pre-service PD ELL/tutored students/Math PD		N, M, SD	Pre-service Teachers
46	Graham	2007	X	X	X	X	P	Structured Collaboration PD-content active learning, coherence-mixed methods		N, M, SD, r	X
47	Owston, Sinclair, & Wideman	2008	X	X	X	X	P	Math & Science PD-face to face & online MS-Student and Teacher ELearning	Pre-Post Teacher and Student	N, M for pre-post	Insufficient data
48	Kleickmann, Richter, Kunter, Elsner, Besser, Krauss, and Baumert	2013	X	X	X	X	P	Ck and PCK-Not PD			Not PD
49	Scher & O'Reilly	2009	X	X	X	X	X	CK, PCK, PD-meta Analysis	Pre-Post, Treatment/Control	N, ES	X
50	Sheralyn Dash Raquel Magidin de Kramer Laura M. O'Dwyer Jessica Masters	2012	X	X	X	X	X	On Line PD 5th grade & Stud. Ach	Corr Knowledge-Pre-Post, Randomly assign, Treatment Group	R, M, SD, N	X
51	Smith, Desimone and Ueno	2005	X	X			P				Not PD
52	Thornton, Crim, and Hawkins	2009	X	X			P	Pre-Kindergarten PD			Not K-12 PD
53	Bailey	2010	X	X	X	X	P	Sustained Standard Based PD 2nd & 3rd grade	Pre-Post Teacher and Student	N, M, SD	X
54	Harrisa, Stevens and Higgins	2011	X	X	X	X	P	Course 1 & 2 MS Teacher PD	Pre-Post-teachers CK growth	N, M, SD, T, F, df	X
55	Telese (REPEAT)	2012									Repeat-duplicate study

56	Carey, Kleiman, Russell, Venable, & Louie	2008	X	X	X	X	P	Online PD-Compare Self pace to Facilitated	Treatment/Control, Pre-Post	N, M, T, ES	X
57	Alvarez	2008	X	No			UNP	Teacher Quality			Not PD-Dissertation
58	Polly, Wang, McGee, Lambert, Martin, and David Pugalee	2014	X	X	X	X	P	Curriculum PD	Pre-Post Teacher and Student	N, M, SD, T, ES	X
59	Polly, Neale, & Pugalee	2014	X	X	X	X	P	Online PD-Math Curriculum Task Focus	Pre-Post Teacher	N, M, SD, T	X
60	Campbell, Nishio, Smith, Clark, Conant, Rust, DePiper, Frank, Griffin and Choi	2014	X	X	X	X	P	Relationship between CK and PD and Student Ach		N, M, SD, ES	Not PD
61	Desimone, Smith and Phillips	2013	X	X	X	X	P	Content Focus PD & Stud Ach	National data set	N, M, r, b	X
62	Krawec and Montague	2014	X	X	X	X	P	Problem Solving PD		%,N,	Not PD
63	Broyles	2009	X	X			P	Gateway Institute for Algebra PD-summer	Teacher Treatment/control, Stud Ach. Foundation math vs Algebra	N, M, SE, F, Mean Diff, Mean square	X
64	Patrick	2014	X	X			P	Meta-analysis of Meta Analysis		r, R^2, T, ES, SE	not sure-too difficult
65	Spiller		X	X			P	Intervention to Response (RTI)-PLC PD-No PD data from SPSLCQ			Does not qualify No CK & PCK
66	Allen	2012	X	X			P	Impact PLC on 3rd grade-mixed methods-Collaboration	Treatment/Control group-Students and Teachers	N, M, SD, Mean diff, F,	X
67	Roher	2012	X	X	X	X	P	Relationship between online Embedded PD for HS Teachers and Stud. Ach	Correlations	r, N, M, SD,	X
68	Wimberley	2013	X	X	X	X	P	Teacher Collaboration PD and Stud Ach. 8th grade	Collaborative vs No Collaborative	N, M, SD, T	X

69	Baumert, Kunter, Blum, Brunner, Voss, Jordan, Krass, Neubrand, and Tsai	2010	X	X			P	Not PD-Germany			Measuring teacher CK and PCK and Student Achievement
70	Erskine	2010	X	X			UNP	Not PD			Not PD-Dissertation
71	Walters	2009	X	X	X	X	UNP	More Theoretical		N, Mean	Insufficient data-Dissertation
72	Lesar	2014	X	X			UNP	Relationship between PLC PD and Student Ach		N, Mean, r	Instead in impact not correlation
73	Jones and Gulek	2010	X	X			P	Math Achievement Curriculum PD			Not PD-comparing high quality teachers to other teachers
74	Benken and Brown	2004	X	X			UNP	Not PD-Exploring PD			Not PD-Insufficient Data-Conference Paper
75	McGehee	2005	X	X			UNP	Coaching/Mentoring PD			Insufficient Data-conference paper
76	Meyer and Wilkerson	2007	X	X			UNP	Lesson Study on PD Models			Insufficient Data-conference paper
77	Poetzl	2005	X	X			UNP	Video PD			Insufficient Data-conference paper
78	Siegfried, Gordon, and Garcia	2007	X	X			UNP	Not PD-How PD effect Teachers Perspective			Not PD-insufficient Data-Conference Paper
79	Fuerborne	2009	X	X	X	X	P	MS Math In-service Course-Content PD (Institute I & II)-6th-8th-5day	Pre-Post Teacher content test	N, M, SD, T	X
80	Van Haneghan, Pruit, and Bambert	2009	X	X	X	X	P	Minority Schools (Project IMPACT PD) CK & PCK, K-5th Math	Treatment/control schools, Trained vs Untrained Teachers	N, M, SD, T	X
81	DiNardo	2010	X	X		X	P	Impact PLC PD on Stud Ach.-Mixed Methods-PK-5th grade	Pre-Post Student	N, M, SD, SEM, T	X

82	Krupa	2011	X	X	X	X	P	Impact of Curricular PD (Core Plus) on Stud. Ach. Summer, follow-up	Pre-Post Students and Teachers	N, M, SD, T, X^2, HLM	X
83	Kuchey, Morrison & Geer	2009	X	X	X	X	P	2 year Initiative for Catholic School ICS Program (1st-3rd grade math). Meet monthly for 2 years and 2 weeks (5 days) in each summer session.	Pre-Posttest teachers and pre-posttest to students; treatment group and control group	N, M, SD, Achievement gain	X
84	Phelan, Choi, Vendlinski, Baker & Herman	2011	X	X		X	P	1 initial meeting and three follow up meetings after each of the first three instructional modules.	Students' Pre-post, treatment and control	N, M, SD	X

Total of 84 Studies (1 duplicate article) →83 Studies→ 47 unqualified → 36 Empirical Studies that could possibly qualify for study→32 studies used an experimental or quasi experimental design
R-Regression, r-Pearson Correlation, SD-Standard Deviation, T-T test, N-Sample size, M-Mean, β-Beta, F-statistics

Appendix E-Coding Manual (16 Studies)

Study 4
Date coded: 3-10-2015

<u>Study identifier</u>

1. Study #: 4
2. Study Authors: O'Dwyer, Masters, Dash, DeKramer, Humez and Russell
3. Year: 2010

<u>Sample Characteristics (randomly assigned to treatment and control groups)</u>

4. Sample size (N):
5. Sample Age (years): 8^{th} grade ranges from 12 to 16
6. Sample grade(s): 5^{th} & 8^{th} graders
7. Proportion male 5^{th} Grade: 90% Teachers females-majority state certified (91%), 58% held masters' degree as highest level, 37% bachelors; 50% students were male and 50% females; Proportion male 8^{th} Grade: 86% Teachers females, 52% females
8. Proportion of ethnicity minority 5^{th} Grade: 89% White teachers, 6% Black-African American, 3% Latino; 65% Students White, 12% Black African American, 13% other (Asian, American Indian, Native Hawaiian, other), 10% provided no race; Proportion of ethnicity minority 8^{th} Grade: 86% White teachers, most identified as white or non-Hispanic.
9. Unique characteristics of sample: 5^{th} grade-Teachers and students for multiple states, 73% of the teachers taught in schools that offer Title 1 services, School locations (towns, rural, city and suburbs)-8^{th} grade teachers from 13 states (majority of teachers taught schools in the south (with a sizable of teachers from the Northeast, and a few from Midwestern or Western states).

<u>Measurement Impact on student achievement</u>

10. Program type on student outcomes- OPD (pre and post)-Education Development Center (EDC)
    - Workshop entailed both theoretical and pedagogical techniques that could be immediately used in the classroom. Learning community model-independent activities and activities to be completed with students in the classroom, and placed a strong emphasis on facilitated peer to peer discussions. Content sessions involved three components: reading, activities, and discussion.

11. Measurement source: 5^{th} Grade Teachers-overall knowledge pre-post survey (fractions, algebraic thinking, measurement knowledge, and overall mathematics knowledge. Student Instrument was to measure changes in students' knowledge in fractions, algebraic thinking, and measurement that might be affected by teachers'

knowledge and instructional practices resulting from OPD. Instrument developed independently from the series of three OPD workshops (reviewed by workshop developers for accuracy and appropriateness of content. Student content knowledge for all three domains was based on released state and national standardized test items. Practices survey (point Likert scale) 8th Grade-65 knowledge questions and 46 practices questions also included 17 questions about teachers' beliefs about pedagogical practices that self-confidence using those practices. Questions were scored 0-1, 0-2, or 0-3.

A) Name of scale: 29 items student (8 fractions, algebraic thinking, measurement knowledge). Scores 1 or 0-correct or incorrect. 4 scores for each student-1 for each content area and 1 for their overall score.

B) Reliability of Instrument-Teachers-overall knowledge pre-post survey (9 fractions, 8 algebraic thinking, 14 measurement knowledge, 31 overall knowledge) had lower than optimal reliabilities ranging from 0.48-0.67. It is desired to have a Cronbach Alpha 0.70. Teacher practice pre-post survey 0.60-0.88. Instrument was to measure changes in students' knowledge in fractions, algebraic thinking, and measurement that might be affected by teachers' knowledge and instructional practices resulting from OPD. Instrument developed independently from the series of three OPD workshops (reviewed by workshop developers for accuracy and appropriateness of content. Student content knowledge for all three domains was based on released state and national standardized test items. Reliability of the pre-test scores on fractions and measurement knowledge scales were quite low (0.49-0.48). Overall mathematics knowledge reliability pre-post 0.73-0.85). 8th Grade-Teacher Overall mathematics knowledge scale reliability 0.70 for pretest and 0.76 for protest. The subsets (16 proportional reasoning knowledge, 12 geometric measurement knowledge, 37 functions knowledge, 65 overall mathematics knowledge, 29 proportional reasoning practice, 10 geometric measurement practice, 7 functions practice)

C) Times versus untimed

12. Duration: Sustained over 7 weeks, participate 4-6 hours per week= appt. 100 hours of OPD

13. Program content:

(content only, pedagogical only, content and pedagogical)

14. Intervention components:
    (workshop only, workshop + coaching, workshop & others)

Design Characteristics

15. Experimental group comparison, quasi-experimental group comparison, single group pre-post comparison, or regression discontinuity designs.

Source Characteristics

16. Published or not publish-to evaluate evidence of publication bias

Study 18

Date coded: 3-12-2015

Study identifier

1. Study #:18
2. Study Authors: McGatha, Bush, Rakes
3. Year: 2009

Sample Characteristics

4. Sample size (N): 40 teachers total-Treatment group (20) middle school math teachers, (7)-6th grade, (6)-7th grade, (7)-8th grade; Teachers in control group (20) were matched to teachers in experimental group by grade level and course taught. Most cases teachers experimental and control group teachers were from the same school.
5. Sample Age (years);
6. Sample grade(s): 6th, 7th, 8th
7. Proportion male:
8. Proportion of ethnicity minority:
9. Unique characteristics of sample: 40 Teachers from 16 schools from twelve districts (urban, rural, or suburban areas)

Measurement Impact on student achievement

10. Program type on student outcomes- Formative Assessment in Middle Mathematics (FAMM) (pre-post) created by the center of Research in Mathematics and Science Teacher Development at the University of Louisville. IMPACT (Increasing the Mathematical Power of All Children

11. Measurement source: Teachers knowledge of rational numbers were assessed through the Diagnostic Teacher Assessment of Mathematics and Science (DTAMS)-a reliable and valid assessment developed by the University of Louisville Center for Research in Mathematics and Science Teacher Development (Saherholm, Ronau, Brown, Collins, in press). This measures the breadth and depth of middle school teachers' mathematics content and pedagogical content knowledge. Student pre-posttest based on assessment containing released fourth-eight grade rational numbers items for (NAEP). It included all 3 levels of DOK 1-3.

A) Name of scale: 20 items (10 multiple choice and 10 open ended)-Teacher released NAEP items.

B) Reliability of Instrument- It satisfies the acceptable standards for validity, internal reliability, equivalency reliability, and inter-scorer reliability, with regards to score in open ended response questions (See Bush, 2006, or Saderholm, Ronau, Brown, & Collins, in press).

C) Times versus untimed

12. Duration: 1 year week-sixty contact hours-(30 hours summer-6 hours for 5 day), monthly meetings (an additional thirty hours) through the school year to encourage and assist MS teachers in integrating formative assessment strategies into their instructional practice.

13. Program content:
(content only, pedagogical only, content and pedagogical)

14. Intervention components:
(workshop only, workshop + coaching, workshop & others)

Design Characteristics

15. Experimental group comparison, quasi-experimental group comparison, single group pre-post comparison, or regression discontinuity designs.

Source Characteristics

16. Published or not publish-to evaluate evidence of publication bias

Study 20
Date coded: 3-17-2015

Study identifier

1. Study #:20
2. Study Authors: Santagata, Kersting, and Stigler
3. Year: 2011

Sample Characteristics

4. Sample size (N): 6th grade middle school math teachers 59 total-Treatment group (33) and control group (26). were matched to teachers in experimental group by grade level and course taught. Most cases teachers experimental and control group teachers were from the same school.
5. Sample Age (years);
6. Sample grade(s): 6th
7. Proportion male:
8. Proportion of ethnicity minority: Hispanic 62% to 95% and Black (18% to 38%).
9. Unique characteristics of sample: Large school district, adopted in the program, district include 5 low performing Title 1. Two schools have regular school year from September-June, The remaining schools follow year round school-program mandatory for all general education 6th grade mathematics teachers. 30% to 47% of the students at each school were English learners. The differences between the control and treatment group of teachers is believe that these differences would not impact teachers participation in the PD program in specific ways.

Measurement Impact on student achievement

10. Program type on student outcomes- Problem Implementation PD was implemented over 2 years but only the first years is included in this study. The control group received the PD the second year and treatment teachers continued for two years. Three topics covered content fractions, ratio and proportion, and expressions and equations. The program consist of three modules each covering on of the content areas, and the respective core concepts. Teachers met in groups of 8 to 10 lead by facilitators. On line math lesson video typed for modules. Teacher learning was structured into three phases: Content Exploration (deeping teachers content knowledge through written documents and video tapes-solve problems from video and post

online answers to questions that fosters understanding), Lesson Analysis (teacher study lesson plan and watch video-taped lesson in which making connection problem was taught) , and Link to Practice (teacher teaches lesson in classroom, collect and analyze students work and share students work with facilitators-led meeting).

11. Measurement source: Teachers knowledge pre-post survey administered prior to and at the completion of the 1st year of PD. 38 multiple choice (total 52 items scored). Items drawn from item bank developed by Deborah Ball, Heather Hill, and colleagues at the University of Michigan in the context of the Learning Mathematics for Teaching project. Other items taken from the Mathematics Professional Development Institutes (MPDIs)-this program is designed to improve mathematics instruction in California (the University of California Office of the President and Patrick Callahan). The survey addresses both CK (38 items- 15 PCK-23 content). The survey consist of 12 fraction items scores (8 PCK), ratio and proportion (14 items-4 PCK-10 content), expressions and equations (26 items- 3 PCK-23 content). Two different forms (A & B-equivalency was established). Half teachers were given form A for pretest, then the control group was given form A for the posttest vice versa. Internal consistency for content items on Form A=.80 and B=.83, and between .66 Form A and .68 Form B for PCK. Teacher cognitive demand used to solve problems during lesson was rated on a 5 point scale-0 math problem not discussed, 1 problem solved using procedures, 2 partial connection t one key mathematical idea in the problem, 3 one conceptual connection was fully included, 4 at least two conceptual connections were included. Students two measures were used to measure student learning: the district-wide Quarterly Assessment (end of each quarter) in preparation for the California Standards test (aggregated scores). These scores were based on 8 fraction problems, 18 targeting ratio and proportion, and 5 targeting expressions and equations. Student learning was also measured by the CST administered at the end of the school year (algebra and functions; operations and problem solving with fractions, and ratios, proportions, percent and negative fractions.

A) Name of scale: 38 multiple choice (total 52 items scored).

B) Reliability of Instrument- It satisfies the acceptable standards for validity, internal reliability, equivalency reliability, and inter-scorer reliability for coded exceeded 85% of lessons and for each code.

C) Times versus untimed

12. Duration: Problem Implementation PD was implemented over 2 years but only the first years is included in this study.

Program content:

13. (content only, pedagogical only, content and pedagogical)

14. Intervention components:
(workshop only, workshop + coaching, workshop & others)-
was supposed to include workshop and coaching-Coaches were asked in the beginning of the year to support the PD program was to remind teachers to teach the target lesson and to support their efforts to teach more conceptually but within a few months after school started they were instructed not to help the 6th grade teachers but to help the seventh and 8th grade to prepare for testing. This was not supported by the coaches or the administration pg. 11

Design Characteristics

15. Experimental group comparison, quasi-experimental group comparison, single group pre-post comparison, or regression discontinuity designs.

Source Characteristics

16. Published or not publish-to evaluate evidence of publication bias

Study 26
Date coded: 3-18-2015

Study identifier

1. Study #:26
2. Study Authors: Ross, Bruce, Hogaboam-Gray
3. Year: 2006

Sample Characteristics

4. Sample size (N): Randomly assigned 106 teachers total-early PD group (Sept-Dec) (treatment group) or Late (Jan.-March) PD group (control group) teachers were from the same school district (all 6th grade teachers in the district).
5. Sample Age (years): student sample represents 24% of the 6th student grade population
6. Sample grade(s): 6th
7. Proportion male:
8. Proportion of ethnicity minority:
9. Unique characteristics of sample: 95% the students are Canadian, only 2% spoke a language other than English, 15% special needs

Measurement Impact on student achievement

10. Program type on student outcomes- PD focused on Reform communication and incorporated principles of effective PD recommended by researchers.

11. Measurement source: Student Achievement was measured with a performance assessment comparable to the mandated assessments conducted by the Education Quality and Accountability Office (EQAO). The performance assessment was shorter (60-90 minutes on each of the three days rather than 150 minutes on each of 5 days. It covered 2 math strands (Number sense and Numeration and Patterning & Algebra), and used different content (i.e Sept assessment used end of 5th grade content; the December assessment used mid-grade 6 content. The assessment was created by the teacher team that produced the 2002 grade 6 mathematics EQAO test. The performance test was field tested in two adjacent districts. Students in both conditions completed the pre-posttest achievement test. The pretest focused on the theme of water and the posttest focused on the theme of wheels.

    A) Name of scale: EQAO Assessment scores ranges from (0-4). The performance test scores ranged from (0-6) to increase discrimination. The pretest (water theme) and the posttest (wheel theme). Each booklet generated 8 scores: four aspects of mathematics achievement (problem solving, concept understanding, application of mathematical procedures, and communication of mathematical ideas) x two strands of mathematics (Number Sense & Numeration Patterning & Algebra). Communications portion was scored by a rubric that provided 4 sets of indicators along with scoring ranging from (1-4). The eight items were measuring a single factor-(facto analysis) mathematics achievement because each score represented one attribute: grade 6 math performance for the pre-posttest for students.

B) Reliability of Instrument-Reliability check (Kappa =.73, .97, .97 respectively for the two coders. Review of the rubric marks. Stemler (2004) suggest that Kappa scores over .60 indicate substantial agreement. All instruments were of adequate reliability. PD program had high internal and external validity. The evaluation of the PD program had high internal and external validity. Internal validity was established by randomly assigning teachers to early and late treatment conditions.

C) Times versus untimed

12. Duration: Pd consisted of 1 full day, followed by (3) 2 hour after school sessions delivered over a ten-week period. 12 hours

13. Program content:
    (content only, pedagogical only, content and pedagogical)

14. Intervention components:
    (workshop only, workshop + coaching, workshop & others)

Design Characteristics

15. Experimental group comparison, quasi-experimental group comparison, single group pre-post comparison, or regression discontinuity designs.

Source Characteristics

16. Published or not publish-to evaluate evidence of publication bias

Study 34
Date coded: 3-31-2015

Study identifier

1. Study #:34
2. Study Authors: Telese
3. Year: 2012

Sample Characteristics

4. Sample size (N): National Center of Educational Statistics (NCES) randomly selected 100 schools from each jurisdiction and then randomly selected 60 students from each school (NCES, 2009c).
5. Sample Age (years);
6. Sample grade(s): 8^{th}-2800 (NCES data set)
7. Proportion male:
8. Proportion of ethnicity minority:
9. Unique characteristics of sample: NAEP employs a complex multistage sampling design. Schools are sampled from each jurisdiction across the country including Washington, DC, and Puerto Rico, and students are sampled from each selected school. Oversampling of some schools is used to ensure that data include these schools with smaller numbers of certain categories (NCES, 2009c).

Measurement Impact on student achievement

10. Program type on student outcomes- 10 types of PD: 1) how students learn; 2) Mathematics Theory or Application; 3) Content standards in mathematics; 4) Curriculum materials available in mathematics (units, texts); 5) Instructional methods for teaching mathematics; 6) Effective use of manipulatives in mathematics Instruction; 7) Effective use of calculators in mathematics instruction; 8) Methods for assessing students in mathematics; 9)Strategies for teaching mathematics to students from diverse backgrounds (including English language learners; 10) Preparation of students for district and state tests.

11. Measurement source: NAEP data Base-8^{th} grade math composite plausible scores. Plausible values are derived variables in response to the complex sampling design with the intent to provide valid estimates of population characteristics (NCES, 2009c). The process involves calculating marginal maximum likelihood estimates, the matrix of effects, and the residual covariance matrix, resulting in five sets of distributional draws called plausible or imputed values, for all sampled students (NCES,

2009c). Teachers' questionnaire given to teachers of students who were randomly selected. The survey asked teachers to indicate the type of professional development activities that they had experienced within the 2 years of taking the survey: 2005 NAEP teacher survey included training in how students learn, learning about mathematics theory, training in the use of curriculum materials, training related to instructional strategies, use of manipulatives, using calculators, training in assessment, training in how to teach diverse students, and training on state mathematics assessment, all of which were used as dependent variables for *t* tests. Note that the 2005 NAEP Grade 8 mathematics teacher survey asked about the extent that teachers attended professional development workshops or seminars, using the categories: (a) not at all, (b) small extent, (c) moderate extent, and (d) large extent, without listing specific number of hours. The response options included "not at all," "small extent," "moderate extent," or "large extent,"coded as 0, 1, 2, and 3, respectively. Parenthetically, the 2005 NAEP teacher survey did not specify definitions for the terms "small extent," "moderate extent," or "large extent."

A) Name of scale: The mathematics composite score is a measure of Overall performance. NAEP provides scale scores in the following content areas of mathematics: (a) geometry, (b) measurement, (c) algebra, (d) data analysis and probability, and (e) number properties and operation. The scale ranges from 0 to 500. There are three levels, basic (262 to 299), proficient (300 to 333), and advanced (334 to 500; NCES, 2009c).
20 items (10 multiple choice and 10 open ended)-Teacher released NAEP items.

B) Reliability of Instrument- It satisfies the acceptable standards for validity, internal and Reliability.

C) Times versus untimed

12. Duration: Approximately 1 year-study did not specific (the durations were large extent of attendance.

13. Program content:

(content only, pedagogical only, content and pedagogical)

14. Intervention components:
    (workshop only, workshop + coaching, workshop & others)

<u>Design Characteristics</u>

15. Experimental group comparison, quasi-experimental group comparison, single group pre-post comparison, or regression discontinuity designs.

<u>Source Characteristics</u>

16. Published or not publish-to evaluate evidence of publication bias

Study 36
Date coded: 3-17-2015

Study identifier

1. Study #:36
2. Study Authors: Heller, Curtis, Rabe-Hesketh, Clarke, & Verbencoeur
3. Year: 2007

Sample Characteristics

4. Sample size (N): 40 schools participated-5 different districts, (32-16 control and 16 treatment) 2nd grade, (38-21 control and 17 treatment) 4th grade, (29-14 control and 15 treatment) 6th grade teachers.
5. Sample Age (years);
6. Sample grade(s): Students MPP Test 2nd (555-284 control & 271 treatment), 4th (755-449 control & 306 treatment), 6th (555-279 control & treatment 276)-only student that completed pre-posttest were included in these analyses.
   Standardize test Students 2nd (137 control & 119 treatment), 4th (186 control & 131 treatment), 6th (158 control & treatment 124)
7. Proportion male: Teachers 89.8% white women, -Students 50% boys and 50% girls
8. Proportion of ethnicity minority: Teachers 73.1% identified themselves as white or 18.3% Black/African American
9. Unique characteristics of sample: 5 different school districts across the nation aiming to represent (Teachers 27.3% urban, 56.6% suburban, 15% rural balanced population. 71.7% had some college mathematics coursework, 27.3% bachelors' degree in math or grad level coursework math, nearly half (42.4%) attended 3 and 6 days of PD in previous years; ¼ of teachers (23.2%) had 7 days or more math PD. Students 17.8%, 18.3%, and 16.6% (2nd, 4th, and 6th grade).

Measurement Impact on student achievement

10. Program type on student outcomes- Math Pathways and Pitfalls (curriculum) PD. In the first year 2nd, 4th, and 6th grade teachers were students randomly assigned in roughly equal treatment or control group in their school districts. The experimental group teachers were taught how to implement (MPP) during one day a six hour PD session in the summer. Teachers (a) received an introduction to the goals and purpose of MPP, (b) observed a video of a class participating in an MPP lesson, (c) participated in a short practicum of how to teacher an MPP lesson. They also attended 2 (2) hour meetings after school; one the beginning of the year and

the other to at the end the wrap up meeting. First year experimental group teachers substituted MPP for a portion of their regular mathematics curriculum. The control group teachers used their regular curriculum and received whatever PD they normally were provided during that year. A totally of 92 teachers and 1,971 students participated in the first year. The study was conducted for two years but the second year data was not recorded in this study.

11. Measurement source: MPP Pitfalls Quiz was given in the beginning of the year(pretest-posttest) given to students at the beginning and ending of the year for each grade level. Items on MPP Quiz assess concepts and procedures that are known to cause difficulty for students as identified by research literature and prominent assessments such as NAEP and TIMSS. Most items multiple choices with one correct answer and contained at least one choice of a common misconception that students have with regards to the concept being assessed; and a few open-ended questions. Mathematics Standardized Achievement tests-districts were asked for test score data for all participating students in study (end of year of previous grade as well as end of current year). Second grade only standardized test were given for the end of second grade, there were no standardized test given at the end of first grade. MPP content covered in PD 2nd grade (whole numbers and operations), 4th grade (fractions), and 6th grade (percents). Three districts out of the 5 districts provided standardized test scores. Three districts used the Stanford Achievement Test, 9th edition (SAT-9), one district used the Missouri Assessment Program Test (MAP) and one district used both the Terra Nova test (TN) and MAP. Teachers completed MPP Questionnaire (background information) and their rating of MPP PD). Standardized test was used for students that were in the MPP analyses 4th and 6th grade because they have a pre-post score. 2nd grade did not have a pretest score.

A) Name of scale: 2nd grade (18 items), 4th grade (17 items), and 6th grade (20 items)-multiple choice and open ended.

B) Reliability of Instrument-MPP Achievement Test Cronbach's Alpha .80 for most all tests.
Except 4th grade 0.42 this was probably due to the overall difficulty of this test, where the average item difficulty was .21

C) Times versus untimed

12. Duration: One PD for experimental teachers. The experimental group teachers were taught how to implement (MPP) during one day a six hour PD session in the summer. Teachers (a) received an introduction to the goals and purpose of MPP, (b) observed a video of a class participating in an MPP lesson, (c) participated in a short practicum of how to teacher a MPP lesson. They also attended 2 (2) hour meetings after school; one the beginning of the year and the other to at the end the wrap up meeting.

13. Program content:
(content only, pedagogical only, content and pedagogical)

14. Intervention components:
(workshop only, workshop + coaching, workshop & others)

Design Characteristics

15. Experimental group comparison, quasi-experimental group comparison, single group pre-post comparison, or regression discontinuity designs.

Source Characteristics

16. Published or not publish-to evaluate evidence of publication bias

Study 50
Date coded: 3-20-2015

Study identifier

1. Study #:50
2. Study Authors: Dash, de Kramer, O'Dwyer, Masters
3. Year: 2012

Sample Characteristics

4. Sample size (N): 79 -Treatment group (34) 5th grade math teachers; Teachers in control group (45)
5. Sample Age (years);
6. Sample grade(s): 1,438 5th grade students-experimental group taught 648, and the control group taught 790.
7. Proportion male: Teachers 90% female; students gender 50%
8. Proportion of ethnicity minority: 89% white, students (65%, white), 12% black, 13% other.
9. Unique characteristics of sample: 79 teachers from 12 states.

Measurement Impact on student achievement

10. Program type on student outcomes- Online PD for 5th grade mathematics teachers. The online PD courses described in this study were three elementary mathematic courses developed by the Education Development Center Inc. for use with teachers of grades 3-5 (EDC) pg. 5 The fifth grade online PD comprised three courses: Using Models to Understand Fractions, Algebraic Thinking in Elementary School, and the Complexities of Measurement.
11. Measurement source: They developed a research instrument to measure teachers' PCK and pedagogical practices as well as student achievement. PCK specifically to subject matter related to fractions, algebraic thinking, and measurement.

    A) Name of scale: Teachers' PCK 31 items-9 items assessed knowledge of fractions, 8 items algebraic thinking, 14 measurement items. We calculated an overall knowledge score as well as three subscale scores for each teacher participant. They calculated mean scores-higher scores indication of high PCK.

B) Reliability of Instrument-Internal consistency reliability overall knowledge 0.72 on pre-survey, and .80 on post survey. Subscale Fractions .54, and .48, algebraic thinking .55 and .60, and measurement .55 and .67. The correlation confirmed statistically significant positive relationship between pre and post PCK subscales r(79)=.20, p=.072. Due to low reliability of subscales and the significant intercorrelation, they conducted analysis with the total scale scores. Reliability overall PCK (4 point scale) .87 pre and .90 post survey. Student's assessment-measurement reliability .82 and .88. Algebraic thinking .82 for both pre and post survey, fractions .61 and .60. Overall math achievement pre .73 and post .85 was used in analyses.

C) Times versus untimed

12. Duration: Online PD courses were offered one course per semester for three semesters, and each course comprised 1 week of orientation and 6 weeks of course content. Overall teachers participated in 70 hours of OPD.

13. Program content:
    (content only, pedagogical only, content and pedagogical)

14. Intervention components:
    (workshop only, workshop + coaching, workshop & others)

Design Characteristics

15. Experimental group comparison, quasi-experimental group comparison, single group pre-post comparison, or regression discontinuity designs.

Source Characteristics

16. Published or not publish-to evaluate evidence of publication bias

Study 58
Date coded: 3-21-2015 :

Study identifier

1. Study #:58
2. Study Authors: Polly, Wang, McGee, Lambert, Martin, and David Pugalee
3. Year: 2014

Sample Characteristics

4. Sample size (N): 53 K-5th grade teachers-all teachers certified to teach elementary school; District A (32) teachers; District B (21) teachers;
5. Sample Age (years);
6. Sample grade(s): K-5th- 688 students
7. Proportion male: 50% of the students were females (344)
8. Proportion of ethnicity minority: Teachers 87% white (46) and 13% black (7); 39% of the students were white (268), 34% African Americans (234), 20% Hispanic (138), 4% Asian (28) and 3% other (21).
9. Unique characteristics of sample: Teachers from 2 school district in Southwestern states of United States participated in PD. District A Large Urban district contains 102 elementary schools (K-5) and employees 3,600 elementary teachers. District B small suburban district that contains 5 elementary schools (k-4th) and one intermediate school (5th-6th). Both districts are considered impoverished –District A 75% qualify for Title 1, District B 100% qualifies for Title 1.

Measurement Impact on student achievement

10. Program type on student outcomes- The U.S Department of Education Mathematics Science Partnership (MSP) Grant designed to support the use of a standards-based elementary school mathematics curriculum, Investigations in Number, Data, and Space (Investigations)-(Russell & Economopoulos, 2007). 3 year funded PD. PD focused on building teachers' knowledge of mathematics content, examining how the mathematics content is embedded into curriculum, and supporting teachers' enactment of reform-based pedagogies. PD designed to support Kindergarten through 5th grade teachers. Same PD materials but each district conducted their own workshops. K-5th teachers met together for all

PD. PD included a learner-centered PD (NPEAT, 2000; Polly & Hannafin, 2010).

11. Measurement source: Teachers practice instrument (TPQ)-self report about instructional practices related to their mathematics teaching (Swan, 2007). 25 items reflects either student centered or teacher centered pedagogies. (5 point likert scale), Cronbach's alpha 0.79. Content Knowledge for Teaching Mathematics Assessment were developed as part of the Survey of Instructional Improvement at the University of Michigan. This project used the Elementary Number and Operation assessments that measures teachers' knowledge of mathematics content and knowledge of students and content (e.g. knowledge related to pedagogy). Student Assessments (end of unit assessments from the Investigations in Number, Data, and Space (Russell & Economopoulos, 2007) elementary mathematics curricula. Three units were assessed from each grade level, and each unit lasted between 3 and 5 weeks. Teacher administered these assessments before teaching the unit (pretests) and immediately after completing the unit (posttests).

A) Name of scale: Teachers' assessment-30 questions (1 point each item)- the total possible score ranges from 0 to 62. These scales have been tested for validity and reliability and have been employed to empirically linked teachers' knowledge to students' achievement. Instrument designed to measure content knowledge in number and operations, patterns, functions and algebra, and geometry, but a total of 62 items. The latest version of Learning Mathematics for Teaching Assessment (LMT; Form A04) was used in this project. Student Assessment-Project evaluators used a standard rubric to score each assessment and converted the score to a percentage that reflects the percent of problems a student solved correctly. Gain scores were used in the analyses.

B) Reliability of Instrument-The reliabilities for subtest for each content knowledge ranged from .72 to .83. and content validity of the instrument had been validated.

C) Times versus untimed

12. Duration: 84 hours of PD between July 2009-April 2010.

13. Program content:
    (content only, pedagogical only, content and pedagogical)

14. Intervention components:
    (workshop only, workshop + coaching, workshop & others)

Design Characteristics

15. Experimental group comparison, quasi-experimental group comparison, single group pre-post comparison, or regression discontinuity designs.

Source Characteristics

16. Published or not publish-to evaluate evidence of publication bias

Study 63
Date coded: 3-21-2015

Study identifier

1. Study #:63
2. Study Authors: Broyles
3. Year: 2008

Sample Characteristics

4. Sample size (N): 6 high school teachers who taught Algebra 1 during the school years from 2004-2007 at one of 4 high schools located in a large school district in West Tennessee. Teachers were assigned to 1 of 2 groups Group A-was comprised of teachers who attended one five day Gateway Institute for Algebra (the Institute) during the summer of 2004, 2005, or 2006; Group B-teachers never attended the Institute. Only teachers of regular level (not honor students were considered). Matched triads of teachers were developed that consisted of two teachers who have attended an Institute (Group A) and one who had not (Group B). Overall the two triads consisted of 5 female teachers and 1 male teacher.
5. Sample Age (years);
6. Sample grade(s): 98 students-9th grade 67, 10th grade 31
7. Proportion male:
8. Proportion of ethnicity minority: 2 Teachers African American and 4 Caucasian
9. Unique characteristics of sample: 5 high schools in the district-one high school were omitted because it offers only Honors Algebra 1 and does not offer Math Foundations 2 at all. 40 teachers from 16 schools from twelve districts (urban, rural, or suburban areas)

Measurement Impact on student achievement

10. Program type on student outcomes- Gateway Institute for Algebra PD activity that was designed and delivered by the Tennessee Department of Education each summer beginning in 2004.

11. Measurement source: Tennessee Comprehensive Assessment Program Achievement Test (TCAP-math8). This assessment is given in the Spring of each year. The Tennessee Comprehensive Assessment Program Achievement Test (TCAP) is a criterion-referenced assessment used to measure student performance levels in Mathematics, Science, Social Studies, Reading, and Language Arts. The TCAP Achievement Tests are timed, multiple-choice tests which are administered each spring to students in grades three through eight (Tennessee Department of Education, 2007a).

Math Foundations II end of course exam score, and the Algebra Gateway Exam score. The Gateway and end-of-course exams were developed by the Tennessee State Board of Education pursuant to TCA 49-1-608 and TCA 49-6-6001(a)(1), which specified that competency must be demonstrated by students in ten secondary courses. Seven assessments have been initiated and consist of three Gateway exams and four end of-course exams. The Gateway Exams are administered in Mathematics (Algebra I or Math for Technology I), Science (Biology I or Biology for Technology II), and Language Arts (English II). In addition to the Gateway exams, the State Board also implemented end-of-course exams for U.S. History, Physical Science, English I, and Math Foundations II. These seven exams are criterion-referenced and are administered three times each year – fall, spring, and summer. The High School Examinations Policy requires that the score on each of these exams must count at least fifteen percent of the final grade in a course. In the school district studied, these exams have a value of twenty percent. While a student's performance on the end-of-course exams impacts the overall grade in those courses, passing scores on the Gateway exams are required for Tennessee students to receive a high school diploma (Tennessee Department of Education, 2007b).

A) Name of scale: Scores on 3 student assessments were obtained (from the Tennessee and the school districts testing supervisor). Student scores on the math subtest of the eight grade Tennessee Comprehensive Assessment Program Achievement Test (TCAP-math8). This assessment is given in the Spring of each year. Math Foundations II end of course exam score, and the Algebra Gateway Exam score.

B) Reliability of Instrument-

C) Times versus untimed - Some examinations are mentioned as being timed

12. Duration: Gateway Institute for Algebra PD-5 day institute

13. Program content:
(content only, pedagogical only, content and pedagogical)

14. Intervention components:
    (workshop only, workshop + coaching, workshop & others)

Design Characteristics

15. Experimental group comparison, quasi-experimental group comparison, single group pre-post comparison, or regression discontinuity designs.

Source Characteristics

16. Published-Dissertation or not publish-to evaluate evidence of publication bias

Study 66
Date coded: 3-21-2015

Study identifier

1. Study #:66
2. Study Authors: Allen
3. Year: 2013

Sample Characteristics

4. Sample size (N): 6 third grade teachers.
5. Sample Age (years);
6. Sample grade(s): 120 Students-60 students randomly selected from the experimental group and 60 students randomly selected from the control group. Control school k-5th grade, experimental school preK—7th grade
7. Proportion male:
8. Proportion of ethnicity minority: Both schools approx. 99% African American, 1% Caucasian.
9. Unique characteristics of sample: two Title I Schools in the West Tennessee urban public school district with third-grade students: Both schools were small (about 500 students each with similar grade structure and demographics) urban elementary schools and each was close in geographic proximity. Experimental school promotion rate 93.7%, Control school promotion rate 90.68%.

Measurement Impact on student achievement

10. Program type on student outcomes- Teacher Collaboration in professional communities PD for 3rd grade math students.

11. Measurement source: Teachscape data (2010-2011) was obtained June 2011 from each principal. The Discovery Education Assessment and Teachscape data collected from the experimental school was compared to the Discovery Education Assessment and Teachscape data from the control group to determine if there was a significant difference in mathematics scores and teaching practices when teachers participate in a mathematics focused professional learning community compared to those who did not participate in a mathematics-focused professional learning community. Discovery Education Assessment district-wide third-grade was given at the midpoint period of each 9-week grading period.

A) Name of scale: Discovery Education Assessment mathematics scores were derived from archival data and were obtained from the director of research (or his appointee) at the Research, Evaluation, and Assessment Department located at the Board of Education

B) Reliability of Instrument-Interrater reliability confirmed at .80 or 80% or higher. Discovery Education Assessment math portion of the formative assessment reliability 0.81 with sample size of 18,252. Teachscape data from both principals. Teachscape is an observation tool used by school administrators to identify the frequency of teaching practices used by teachers. The test reliability is valid when administrators are trained to have the same understanding of observed components. The information was compiled to compare the frequency of teaching practices between the experimental and control school. The information was utilized to examine whether there was a difference in teaching practices when teachers participate in mathematics-focused professional learning communities compared to those who did not participate in a mathematics-focused professional learning community.

C) Times versus untimed

12. Duration: year round PD for Teachers- Discovery Education Assessment given at the midpoint of each 9-week periods in the months of September, November, and February to measure the students' math performance level.

13. Program content:
(content only, pedagogical only, content and pedagogical)-teaching strategies and grouping formats being compared between each school

14. Intervention components:
(workshop only, workshop + coaching, workshop & others)-collaboration

Design Characteristics

15. Experimental group comparison, quasi-experimental group comparison, single group pre-post comparison, or regression discontinuity designs.

Source Characteristics

16. Published-Dissertation or not publish-to evaluate evidence of publication bias

Study 68

Date coded: 3-22-2015

Study identifier

1. Study #:68
2. Study Authors: Wimberley
3. Year: 2013

Sample Characteristics

4. Sample size (N): 100 public school districts were randomly selected; 50 Collaboration (Treatment) and 50 Non Collaboration (Control).
5. Sample Age (years);
6. Sample grade(s): 8th Grade
7. Proportion male:
8. Proportion of ethnicity minority:
9. Unique characteristics of sample: 100 public school districts in Missouri

Measurement Impact on student achievement

10. Program type on student outcomes- Collaborative PD- The pedagogical model espoused by Howland and Picciotto (2003b) defined teacher collaboration as a pedagogy that involves two or more teachers who regularly discuss teaching and learning, including learning activities, lesson plans, assignments, pacing, course design, evaluating, and revising the program. Collaborative school districts were distinguished from non-collaborative school districts as districts that used contracted time, or time embedded within the school day, for staff to collaborate. Non-collaborative school districts did not meet during contracted time; collaboration occurred during workshops, book studies, and planning during the school day.

11. Measurement source: Online survey addressed to Professional Development Chairpersons in Missouri Teacher survey consisting of 15 questions in a multiple-choice and Likert-scale format. Eighth grade student achievement scores in Communication Arts and Math from the 2009-2010 Missouri Assessment Program (MAP). The MAP, was selected to obtain the proficient and advanced scores of eighth grade students in the areas of Communication Arts and Math for 2010. The MAP is

administered each spring to students in Missouri public schools to determine academic growth. The assessment is an accountability tool that is used to meet the mandates of No Child Left Behind. Student scores on the MAP fall into one of four levels of achievement: Below Basic, Basic, Proficient, or Advanced.

A) Name of scale: The survey consisted of 15 questions framed around teacher collaboration.

B) Reliability of Instrument-MAP-Researchers confirmed, “We have very firm evidence that the MAP assessments yield scores that are valid, given the stated purpose of the program” (MODESE, 2008, p. 4). Online Survey The survey was field-tested to obtain comments and suggestions from educational peers and colleagues and then revised to assure clarity and readability.

C) Times versus untimed

12. Duration: Year round

13. Program content:
    (content only, pedagogical only, content and pedagogical)

14. Intervention components:
    (workshop only, workshop + coaching, workshop & others)

Design Characteristics

15. Experimental group comparison, quasi-experimental group comparison, single group pre-post comparison, or regression discontinuity designs.

Source Characteristics

16. Published Dissertation or not publish-to evaluate evidence of publication bias

Study 80
Date coded: 3-22-2015

Study identifier

1. Study #:80
2. Study Authors: Van Haneghan, Pruet, and Bamberger
3. Year: 2004

Sample Characteristics

4. Sample size (N): 4 schools MMI project and 2 control schools that were demographically similar.
5. Sample Age (years);
6. Sample grade(s): 2nd Grade (T)-153 and (C)-41; 5th Grade (T)-277 and (C)-85
7. Proportion male:
8. Proportion of ethnicity minority: Majority of students in all schools were 98% black;
9. Unique characteristics of sample: 4 high poverty predominately urban schools, demographically mixed public school system in the South. 4 schools varied in size student population ranges from 300 to 800. They are part of a countywide school district that serves 65,000 students and is the largest in the state. The district historically is underfunded—in the spring of 2000, the first property tax increase in 40 years was passed. 85% to 99% receiving free lunch based on 2001-2002 data.

Measurement Impact on student achievement

10. Program type on student outcomes- IMPACT (Increasing the Mathematical Power of All Children and Teachers), a project implementing intensive PD in schools in Maryland. The mathematics component of the professional development is based on the recommendations put forth by the National Council of Teachers of Mathematics (NCTM) concerning standards for school mathematics (NCTM, 1989, 2000a). The prevailing research on improving student achievement in high-poverty schools and regarding best practices in professional development has driven the design of the MMI (Campbell & White, 1997; Knapp et al., 1995; Loucks-Horsley,Hewson, Love,&Stiles, 1998; National Staff Development Council, 2001).

11. Measurement source: All students were tested using 2 test-Items from the Third International Math/Science Study (TIMSS) Data set publicly released item sets and Stanford Achievement Test Scores-9

(SAT-9 scores)-percentile scores for the students and schools (Alabama State Department of Education 2002).

A) Name of scale: TIMSS Data set and Stanford Achievement Test Scores. The difficulty levels of the items were matched to the grade levels of the students. There were 11–12 items on these TIMSS item tests. TIMSS and Standford scores were examined each year. Rather than sampling students the TIMSS and Standford test were given at all students at each grade level.

B) Reliability of Instrument- It satisfies the acceptable standards for validity, internal reliability.

C) Times versus untimed

12. Duration: 3 years PD project in Mathematics for 4 predominantly minority urban elementary schools. MMI summer institutes involved only 10 days.
13. Program content:
    (content only, pedagogical only, content and pedagogical)

14. Intervention components:
    (workshop only, workshop + coaching, workshop & others)

Design Characteristics

15. Experimental group comparison, quasi-experimental group comparison, single group pre-post comparison, or regression discontinuity designs.

Source Characteristics

16. Published or not publish-to evaluate evidence of publication bias

Study 81
Date coded: 3-23-2015

Study identifier

1. Study #:81
2. Study Authors: DiNardo
3. Year: 2004

Sample Characteristics

4. Sample size (N): 6 teachers total- The six teachers were selected from the 7 third grade teachers and 5 fifth grade teachers, a total of 12 teachers. The teachers selected were from the first six to turn in name as a volunteer to participate in the study.
5. Sample Age (years);
6. Sample grade(s): 121 students-(3rd and 5th grade)- The convenience sample was selected to be approximately one-half of the teachers and students in the participating grade-levels. The students selected were students enrolled in the participating teachers' classrooms.
7. Proportion male:
8. Proportion of ethnicity minority: 37.33 Black, 19.6 Hispanic, 8.98 other, and 34.07 White
9. Unique characteristics of sample: School population 857 students in grades pre-K through fifth in the southeastern United States. 53% free lunch. Because the teachers participated on a volunteer basis and the students were not taking any extra assessments, all students were eligible to participate.

Measurement Impact on student achievement

10. Program type on student outcomes- Professional Learning Communities (PLC)- All professional learning sessions explored and introduced research-based techniques and strategies to help teachers improve student learning in their classrooms. Sessions were held on oral reading fluency and the connection between math skills and strategies.

11. Measurement source: A semi structured, open-ended interview. The interview questions were developed by the researcher (see Appendix A) to determine their participation in professional learning and how they were able to use information in their classroom.

Students participated in two assessments (DIBELS and OAS) to see if student learning had improved as a result of the improved classroom instruction. These professional learning communities shared student data in on-going sessions to determine the needs of the participants.

Georgia Department of Education Online Assessment (OAS): Tests that consist of the same kinds of questions as appear on the state's assessments in Reading, English/Language Arts, Mathematics, Science, and Social Studies in the Criterion-Referenced Competency Tests (CRCT), the End of Course Tests (EOCT), and the Georgia High School Graduation Tests (GHSGT; Georgia Department of Education, 2004).

The online assessment (OAS) is given to all of the students in the computer lab and results are retrieved from a system database.

A) Name of scale:

B) Reliability of Instrument-Reliability has been established over the 4 year period the system has used these assessment measures. Validity has been established as DIBELS measures ORF and OAS measures the standards learned by the student.

C) Times versus untimed

12. Duration: The teachers participated in three 2-hour sessions (6 hours) directed by the instructional coach and the researcher. The professional learning plan was implemented in three sessions; each was held after school in a comfortable setting where teachers were not hurried to get to their next task. Interviews lasted approximately 20 minutes in length each and took place after school hours in the school conference room. Questions were open-ended and the participants' responses were recorded.

Students were given the assessments twice during the study. It is a computer-based test that takes approximately 45 minutes for each session. These assessments were both given in October, at the beginning of the study, and again in November or December to determine any increase in scores in oral reading and math after professional learning sessions were attended by the teachers.

13. Program content:

(content only, pedagogical only, content and pedagogical)

14. Intervention components:
    (workshop only, workshop + coaching, workshop & others)

Design Characteristics

15. Experimental group comparison, quasi-experimental group comparison-mixed-methods (concurrent nested strategy), single group pre-post comparison, or regression discontinuity designs.

Source Characteristics

16. Published-Dissertation or not publish-to evaluate evidence of publication bias

Study 82

Date coded: 3-23-2015

Study identifier

1. Study #:82
2. Study Authors: Krupa
3. Year: 2011

Sample Characteristics

4. Sample size (N): The subset of Algebra I EOC data for workshop participants was provided for 48 schools. Twelve schools offered Algebra 1 integrated mathematics and 37 offered Subject-Specific Algebra 1 mathematics (one offered both). There were 15 Algebra 1integrated mathematics teachers and 51 Subject-Specific-Algebra 1 mathematics teachers included in this sample (three teachers taught both curricula). Algebra 2 the subset of Algebra II EOC data for workshop participants was provided for 35 schools. Five schools offered integrated mathematics and 32 offered subject-specific mathematics (two offered both). There were eight Algebra 2 integrated mathematics and 36 subject-specific mathematics teachers included in this sample (one teacher taught both curricula)
5. Sample Age (years);
6. Sample grade(s): [572 students Algebra 1integrate Course 2-(9^{th}-12^{th})], Subject Specific Algebra 1-[1,986 students (6^{th}-12^{th})]; Algebra 2[290 students Algebra 2 integrate Course 3-(9^{th}-12^{th})], Subject Specific Algebra 2-[1,689 students (9^{th}-12^{th})];
7. Proportion male: Algebra 1 (integrate females 61%), Subject Specific (50.06 Females); Algebra 2.
8. Proportion of ethnicity minority: Algebra 1 Integrated (Asian 7.34%, Hispanic 11.89%, Black 30.07%, White 45.80%, Multi 3.15%); Subject Specific Algebra 1(Asian 1.21%, Hispanic 8.26%, Black 36.86%, White 48.48%, Multi 2.52%); Algebra 2 Integrated and Algebra 2 Subject Specific.
9. Unique characteristics of sample: Algebra 1 Integrated (Course 2)free reduced lunch-FRL 52.07%, ADM 499.64, Tile One 25%, NCNSP 75.00; Algebra 1 Subject Special FRL 49.12%, ADM 694.43,Title one 2.70%, NCNSP 35.14- Schools offering integrated mathematics had a slightly higher %FRL, lower average daily membership, and were more frequently classified as Title One or as a North Carolina New Schools Project School (NCNSP) school than the schools with Algebra I students (Table **20**). Integrated mathematics teachers were exposed to about 45 additional hours of NCIM professional development than subject-specific teachers, while subject-specific teachers tended to have 5 more years of teaching experience. Algebra 2 Integrated Course 3- Algebra 2 Integrated (Course 3) free reduced lunch-FRL 72.85%, ADM 275.25, Tile One 60%, NCNSP 100.00; Algebra 2 Subject Special FRL 49.81%, ADM 605.93,Title one 3.13%, NCNSP 56.25-Schools offering integrated mathematics had a higher %FRL, lower average daily membership, and were more frequently classified as Title One than the schools with Algebra II students (Table **27**). All of the schools offering Course 3 were involved in the NCNSP.

Measurement Impact on student achievement

10. Program type on student outcomes- Integrated reform-based curriculum, Core-Plus- The Core-

Plus program integrates four strands (Algebra and Functions, Geometry and Trigonometry, Statistics and Probability, and Discrete Mathematics) across the first three years of high school mathematics, with an optional fourth year course, to prepare students for college mathematics (Hirsch, Fey, Hart, Schoen, & Watkins, 2008). North Carolina Integrated Mathematics1 (NCIM) project. The NCIM project was developed to create and support a community of teachers using the *Core-Plus Mathematics* (CPMP)2 (Coxford, et al., 2001) integrated curriculum materials, particularly in high needs schools, and to study and evaluate the effectiveness of its use in these settings. NCIM a state- funded professional development program with the elements of a summer program, follow-up workshops, and monthly site based support with instructional coaches.

11. Measurement source: Students' Statewide End of Course exams (EOC-Algebra I and II) from 2009-2010 (North Carolina Department of Public Instruction (NC-DPI). Teacher level-Instruments at the teacher level included Table of Contents Records (TOC-log), content knowledge assessment, background questionnaire, beliefs survey, instructional coach reports, semi-structured interviews, and classroom observations. Each of these will be explained in more detail below.

    A) Name of scale:

    B) Reliability of Instrument-It satisfies the acceptable standards for validity, internal reliability, equivalency reliability, and inter-scorer reliability.

    C) Times versus untimed

12. Duration: Professional development program with the elements of a summer program, follow-up workshops, and monthly site based support with instructional coaches. The NCIM project directors and evaluation team designed four components for the NCIM professional development. Each year, the four main elements of the professional development model were (1) a summer workshop providing in-depth education on use of curricular materials (one or two weeks), (2) a web-based environment supporting information exchange, (3) two face-to-face follow-up conferences, and (4) instructional coaches who visited each site monthly

13. Program content:
    (content only, pedagogical only, content and pedagogical)

14. Intervention components:
(workshop only, workshop + coaching, workshop & others)

Design Characteristics

15. Experimental group comparison, quasi-experimental group comparison-mixed methods (embedded correlational model), single group pre-post comparison, or regression discontinuity designs.

Source Characteristics

16. Published-Dissertation or not publish-to evaluate evidence of publication bias

Study 83
Date coded: 3-23-2015

Study identifier

1. Study #:83
2. Study Authors: Kuckey, Morrison, & Geer
3. Year: 2009

Sample Characteristics

4. Sample size (N): The Initiative for Catholic Schools (ICS) Program designed to improve teaching strategies and content knowledge in science and mathematics and school leadership. One goal was to improve students learning and retention in basic science and mathematics content and to implement a student-orientated pedagogy. 21 Catholic schools submitted a proposal as was accepted into the program. 21 school teams were selected from the 77 that were invited. Teams consisted of at least one science teacher, at least one mathematics teacher, and the school principal. 24 Math teachers from the 21 schools all were females. There were 22 math teachers that participated in the ICS program at the end of the second year. ICS pd addressed teachers' content knowledge and in the areas of probability, geometry, algebra, and measurement. Increasing teachers' pedagogical knowledge was also part of the pd.

5. Sample Age (years);
6. Sample grade(s): 1st grade 118 students, 2nd grade 99 students, 3rd grade 265 students 7.
7. Proportion male:
8. Proportion of ethnicity minority: Asian ranges (0% to 5.8%); Hispanic or Pacific Islander ranges (0% to 2.9%); Black ranges (0% to 96.8%); White ranges (0% to 100%); American Indian or Alaskan ranges (0% to 0.6%); Multi ranges (0% to 7.2%)
9. Unique characteristics of sample: The 24 participating Catholic Elementary (urban, suburban, and rural) schools located in a Midwestern city were diverse in socioeconomic status, ethnic backgrounds, and location. Economically disadvantage schools districts ranges from (0% to 90.8%) from the ICS schools and the 3 comparison schools.

Measurement Impact on student achievement

10. Program type on student outcomes- The Initiative for Catholic Schools (ICS) Program designed to improve teaching strategies and content knowledge in science and mathematics and school leadership. One goal was to improve students learning and retention in basic science and mathematics content and to implement a student-orientated pedagogy. ICS pd addressed elementary teachers' content knowledge in the areas of probability, geometry, algebra, and measurement. Increasing teachers' pedagogical knowledge was also part of the pd. This professional development was based on a

model proposed by Guskey (2000) for evaluating the impact of professional development that is comprised of five levels: (a) participants' reactions, (b) participants' learning, (c) organization support and change, (d) participants' use of new knowledge and skills, and (e) student learning outcomes.

11. Measurement source: University faculty members with expertise in science and math education developed the Standards-Based Tests of Achievement in Math and Science. The items for 1st-3rd grade were taken from Ohio Diagnositc Test. This test content was available in the form of sample test questions from the state Department of Education website (Ohio Department of Education, 2008).

   A) Name of scale: Grade 1 Geometry 10 items and Probability 13 items; Grade 2 Geometry 10 items and Probability 10 items; Grade 3 Geometry 16 items and Probability 14 items.

   B) Reliability of Instrument-It satisfies the acceptable standards for validity, internal reliability, equivalency reliability, and inter-scorer reliability.

   C) Times versus untimed

12. Duration: The ICS program was a 2-year professional development program designed to improve teaching strategies and content knowledge in science and mathematics and school leadership. The participants met for monthly workshops during the academic year and for 2 weeks in each summer session (5days per week). The summer sessions were taught by the University Faculty members whose areas of expertise were science and mathematics education. The goals of the ICS program are: (a) to develop and strengthen leadership in Catholic elementary schools, (b) to improve the curriculum in science and mathematics, (c) to improve student learning and retention in basic science and mathematics content, and (d) to implement a student-oriented pedagogy.

13. Program content:
    (content only, pedagogical only, content and pedagogical)

14. Intervention components:
    (workshop only, workshop + coaching, workshop & others)

Design Characteristics

15. Experimental group comparison, quasi-experimental group comparison, single group pre-post comparison, or regression discontinuity designs.

Source Characteristics

16. Published or not publish-to evaluate evidence of publication bias

Study 84
Date coded: 3-23-2015

Study identifier

1. Study #:84
2. Study Authors: Phelan, Choi, Vendlinski, Baker & Herman
3. Year: 2011

Sample Characteristics

4. Sample size (N): 85 teachers from 27 schools in 7 school districts participated in a random assignment implementation study.
5. Sample Age (years);
6. Sample grade(s): 6th grade students; Between Schools 633 (control), 842 (treatment), total 1,475; Within Schools 1,120 (control); 1,496 (treatment), total 2,616
7. Proportion male:
8. Proportion of ethnicity minority: See table 3
9. Unique characteristics of sample: Student characteristics for participating schools are presented in Table 3. In all four districts, the percentage of students who were below proficiency in mathematics the previous year was between 24% and 53%, with an average of 50% (41%–57%). The percentage of English learner students ranged from 10% to 26%.

Measurement Impact on student achievement

10. Program type on student outcomes- Formative Assessment for Middle School Mathematics starting in 6th and on helping assure that students learn the fundamental mathematical principles intended to support mastery in algebra. The focus on algebra is motivated by ample research showing the frequency and price of failure for subsequent academic performance, including high school graduation, college entry and preparation (e.g., Brown & Niemi, 2007). Within each of the selected content areas we designed a series of short formative assessments (*Checks for Understanding*) to help Grade 6 teachers assess their students' understanding of basic mathematical principles, and to connect their instruction and provide feedback to support deeper understanding.

11. Measurement source: The intervention targets big ideas and related skills in four domains underlying success in Algebra 1: (a) rational number equivalence (RNE), (b) properties of arithmetic (PA; the distributive property), (c) principles for solving linear equations

(SE), and (d) application of core principles in these domains to other critical areas of mathematics, such as geometry and probability (RA). These domains were chosen because of their importance to later mastery of algebra and their significant place in state mathematics standards across Grades 6–8.item tests. The test of prerequisite knowledge served as a baseline measure for later analyses. The pretest consisted of 28 items modeled after items on the released state test items for Grade 5, and items used and validated on other projects. These items addressed concepts covered within the scope of the project. *Transfer Measures (Posttest)* developed a transfer measure using items from several sources including the Trends in International Mathematics and Science Study, National Assessment of Educational Progress, the Qualifications and Curriculum Authority Key Stage 3 exam, Programme for International Student Assessment, and benchmark tests used in one of our pilot districts. Items were selected based on their relevance to the study domains and their appropriateness for a transfer task (i.e., related to study content, but not exact replicas of item types used in the *Checks for Understanding*). A final set of items (29) was selected. Of these items, 19 were multiple choice, nine were short answer, and one was an explanation. The transfer measure was given to all participating students (N = 5,358) at the culmination of the study year.

A) Name of scale: To investigate the quality of the test items we used the one Parameter logistic model (1PLM) for dichotomous items and partial credit model (PCM; Masters, 1982) for polytomous items. This choice is in line with findings in Phelan et al. (2009), which showed the appropriateness in using unidimensional Rasch models for study test items. Additionally, with the data sets for the pretest and transfer measure having items representing all domains, factor analysis was conducted to estimate the amount of variance explained by the main construct.

B) Reliability of Instrument- It satisfies the acceptable standards for validity, internal reliability. Table 5 shows the number of items, the actual number of examinees, and reliability for the pretest and the transfer measure. The reliability was computed with coefficient alpha. The reliability coefficient for the pretest was .8 and for the transfer measure was .86.

C) Times versus untimed

12. Duration: 1 year (2007-2008)-Teacher received 9 hours of Formative Assessment PD. PD consisted of an initial meeting during which teachers were given an overview of the study objectives and the theoretical underpinnings of the project. Three follow-up meetings (after each of the first three instructional modules) were also a part of the professional development.

13. Program content:
    (content only, pedagogical only, content and pedagogical)

14. Intervention components:
    (workshop only, workshop + coaching, workshop & others)

Design Characteristics

15. Experimental group comparison (random assignment), quasi-experimental group comparison, (mixed method design), single group pre-post comparison, or regression discontinuity designs.

Source Characteristics

16. Published or not publish-to evaluate evidence of publication bias

Appendix F-Quantitative Data Coding Matrix (31 Studies)

Paper No.	Authors	Year	PD Type	CK	PCK	Grade Level	Sample Size Student (C)	Sample Size Student (T)	Sample Size Teacher (C)	Sample Size Teacher (T)	Duration	Intervention components	Student Outcomes Pre	Student Outcomes Post	Effect Sizes	Teacher Outcomes Pre	Teacher Outcomes Post	Control Group	Data-Sample, Mean, & SD	Notes
1	Patel, Franco, Miura, and Boyd	2012	Content Focus PD-curriculum PD	X	X	6th			Teacher 26	Teacher 26	1 week CMP2 workshop-40 hours	Workshop only				M-60.00, SD=26.2	M-67.02, SD=26.2 significant different t test on pre and post- test total score t(24)=-2.84, p=.01, a paired sample t test examining the difference between 6th grade pre-post sub scores of each of the 4 knowledges, t(24)=-1.24, p=.001 Normalize gains scores .08, p=.01	Pre-Post WS. assessment for teachers CK, PCK	N, M, SD, T-Test, Z scores, P values	X-No student outcomes.

4	O'Dwyer, Masters, Dash, DeKramer, Humez and Russell	2010	On line PD	X	X	5th & 8th	5th- 790 8th-1062	5th- 648 8th- 799	5th- 45 8th- 43	5th- 34 8th- 28	Teacher treatment Group- Sustained over 7 weeks, participate 4-6 hours per week= appt. 100 hours of OPD	Treatment Group 3 workshops- Spring, Fall, then Spring next year- Included both theoretical and pedagogical techniques.		Pre to Post Scores 5th Grade Fract(T)- ΔM=.1735, SD=0.17, SD=0.24; Fract(C)- ΔM=0.139, SD=0.18, SD=0.25; Algebraic(T)- ΔM=0.114, SD=0.23, SD=0.25; Algebraic(C)- ΔM=0.078, SD=0.23,, SD=0.25; Measure (T)- ΔM=0.098, SD=0.20, SD=0.22; Measure(C)- ΔM=0.072, SD=0.20, SD=0.21 Overall 5th grade 5th (T)=ES=0.48, ΔM=0.127, SD=0.16, SD=0.21; 5th (C)=ES=0.36, ΔM=0.092, SD=0.16, SD=0.20 Pre to Post Scores 8th Grade Prop Reason(T)- ΔM=0.009, SD=0.15, SD=0.16; Prop Reason(C)- ΔM=0, SD=0.16, SD=0.16 Geom Meas(T)- ΔM=0.054, SD=0.19, SD=0.23; Geom Meas(C)- ΔM=0.041, SD=0.19, SD=0.22; Functions (T)- ΔM=0.094, SD=0.17, SD=0.17; Functions(C) ΔM=0.080, SD=0.17, SD=0.14; Overall 8th grade 8th (T)=ES=0.15, ΔM=0.029, SD=0.13, SD=0.14 8th (C)=ES=0.10, ΔM=0.019,	5th Grade Change in Knowledge Fractions ES 0.09 Algebraic ES 0.07 Measure ES 0.06 Overall Math Knw ES .10 8th Grade Change in Knowledge Prop Reason ES 0.04 Geom Measure ES 0.07 Functions ES 0.01 Overall Math Knw ES 0.06	5th Grade- Overall Teachers' Knowledg e pre- post Treatmen t ES=0.58, Teacher overall Pre-post Practice ES=0.37	5th Grade-Overall Teachers' knowledge pre- post Control ES=- 0.06, Teacher overall Post- Practice ES=0.026	Treatment/ Control Group Teacher/Stu dents	SD, M, ES, Ancova T	X

														SD=0.13, SD=0.14						

5	Russell, Kleiman, Carey, and Douglas	2009	Chortbased On line course	X	X													PRE-Post Teacher CK, PCK	N, M, SD, ES	X-No student outcomes.
7	Russell, Carey, Kleiman, and Venable	2009	Same course On line PD/Face to Face	X	X													Pre-Post Treatment Group	N, M,	X-No student outcomes.
13	Sherin and Van Es	2009	Video PD		X													Pre-Post Teacher	N, M, SD,	X-No student outcomes.
17	Hill, Ball	2004	California's Math PD CK	X														Teachers Pre-Post test	N, M, SD, Beta HLM, Anova	X-No student outcomes.
18	McGatha, Bush, Rakes	2009	PD Formative Assessment	X	X	6th-8th	6th-87 7th-96 8th-138	6th-7 7th-6 8th-7	6th-7 7th-6 8th-7	6th-98 7th-127 8th-109	1 year sixty contact hours-30 summer hours(6 hours 5 days- monthly meetings addition 30 hours.	Workshop & Others	6th (T)-N=98, M=13.143, SD=6.3098 6th (C)-N=87, M=13.207, SD=5.745; 7th (T)-N=127, M=12.677, SD=5.161 7th (C)- N=96, M=15.229, SD=6.339; 8th (T)-N=109, M=16.982, SD=6.308 8th (C)-N=138, M=19.029, SD=5.727	6th (T)-N=98, M=13.204, SD=6.082 6th (C)-N=87, M=16.379, SD=6.695; 7th (T)- N=127, M=20.149, SD=5.515 7th (C)- N=96, M=17.313, SD=7.358; 8th (T)- N=109, M=19.716, SD=6.068 8th (C)- N=138, M=22.703, SD=5.981				Teachers Pre- Posttest, Control Group, Stud Ach	Teache r ES,STD. Mean, df, T test, F,	X
20	Santagata, Kersting, and Stigler	2011	PD Teachers' CK, PCK	X	X	6th	Pre Test N=2,559	Post Test N=2,564	Teacher 26	Teacher 33	1 year Problem Implement ation PD	Workshop & Coaching	6th CST Pre Test -N=2,559, M=305.71, SD=62.29	6th Quarterly Post- N=2,564, M=14, SD=7.17;				Treatment/ Control Group Teacher/Stu dents (pre- posttest)	N, M, SD, T, W, ES, B,	X

26	Ross, Bruce, Hogaboam-Gray	2006	Impact Pd on Student 6th grade	X	X	6th-106 Randomly Assigned teachers	Motivation Variables Jan(1) N=310, Jan (2)N=309, Jan (3)N=309, Jan (4)N=309, Jan (5)N=308, Jan(6)N,309, Jan(7)N=309, Jan(8)N=309;	Motivation Variables Sept(1)N=406, Sept(2)N=408, Sept(3)N=408, Sept(4)N=408, Sept(5)N=406, Sept(6)N=408, Sept(7)N=408, Sept(8)N=407	6th-106 teachers	6th-106 teachers	1 full day and 3 (2) hour sessions=12 hours-10 week period	workshop and others	Motivation Control Variables Jan(1) N=310, M=4.50, SD=0.88; Jan (2)N=309, M=4.38, SD=1.18, Jan (3)N=309, M=3.44, SD=1.29 Jan (4)N=309, M=2.87, SD=1.28, Jan (5)N=308, M=2.98, SD=1.16, Jan(6)N,309, M=4.96, SD=0.76, Jan(7)N=309, M=2.38, SD= 1.03, Jan(8)N=309; M=4.71, SD=0.89	Motivation Treatment Variables Sept(1)N=406,M=4.39, SD=0.85, Sept(2)N=408, M=4.41, SD=1.13, Sept(3)N=408, M=3.39, SD=1.30, Sept(4)N=408,M=2.85, SD=1.28, Sept(5)N=406,M=3.02, SD=1.16, Sept(6)N=408, M=5.01, SD=0.68 Sept(7)N=408,M=2.51, SD=1.11, Sept(8)N=407, M=4.79, SD=0.89 T-values (1) t=-1.640, df=714, p=0.101; (2) t=0.450, df=715, p=0.730; (3)t=-0.454, df=715, p=0.650; (4)t=-0.239, df=715, p=0.811; (5)t=0.461, df=712, p=0.645; (6)t=0.992, df=715, p=0.322; (7)t=1.566, df=715, p=0.118; (8)t=1.242, df=714, p=0.215;	Total Treatment Group received PD (May 2004) increased Student math ach increased from 2003 to 2004 on the EQAO Assessment ES=.10, t=(6105)=3.37, p<.001-small effect size			Teacher Treatment/ Control Group, Student pre-post test	N, M, SD, T, ES, F	X-Not United States-Canada-EQAO Test there was adjusted post means on page 566-not sure what to do with them.
31	Bell, Wilson, Higgins, McCoach	2010	Effect PD on Teachers' Knowledge	X	X													Pre-post, Treatment Group	N, M, SD, ES	X-No student outcomes.

34	Telese	2012	MS reform PD CK and PK on Stud Ach 8 NAEP	X	X	8th Grade-randomly selected from NAEP 100 randomly selected	No PD PD 1(C) N=365,583 M=280.73 SD=35.93; PD2(C) N=662,465 M=280.97 SD=35.38; PD3(C) N=167,091 M=277.61 SD=35.96 PD4(C) N=269,893 M=278.19 SD=35.84; PD5(C) N=260,416 M= 279.53 SD=35.68; PD6(C) N=536,594 M=282.02 SD=35.11; PD7(C) N=798,696 M=278.20 SD=35.15; PD8(C) N=478,616 M=280.80 SD=35.88; PD9(C) N=1,184,775 M=283.65 SD=34.69; PD10(C) N=384,499 M=282.77 SD=35.90	Large PD PD 1(T) N=596,287 M=278.63 SD=36.24; PD2(T) N=393,017 M=278.00 SD=36.49; PD3(T) N=1,501,197 M=279.98 SD=35.40; PD4(T) N=946,590 M=279.97 SD=36.17 PD5(T) N=898,936 M=278.63 SD=36.19; PD6(T) N=570,374 M=278.25 SD=36.41; PD7(T) N=482,301 M=280.55 SD=37.55; PD8(T) N=507,600 M=277.33 SD=36.43; PD9(T) N=260,479 M=272.14 SD=37.54; PD10(T) N=1,103,223 M=279.81 SD=35.12			Small extent; Moderate extent; Large extent	Work only; Workshop & Others						Teacher randomly selected of students-Control and Treatment Control group-No PD and Treatment Group (small extent, moderate extent, and large extent of PD over the last 2 years in 10 different types of PD.	N, R2, SE, M, SD, T, ES	X-10 different PD with No treatment as control
36	Heller, Curtis, Rabe-Hesketh, Clarke, & Verbencoeur	2007	Impact Math Pathways and Pitfalls (MPP) Curriculum based on 2nd, 4th, 6th grade students	X	X	2nd, 4th, 6th	MPPS Sample 2nd-284 4th-449 6th-279 Stand sample 2nd-137 4th-186 6th-158	MPPS Sample 2nd-271 4th-306 6th-276 Stand sample 2nd-119 4th-131 6th-124	2nd-16 4th-21 6th-14	2nd-16 4th-17 6th-15	1 year curriculum implemenation-1 (6) hour workshop and 2 (2) hour meeting beginning and end of year.	workshop and others	MPP Quizes 2nd (T)-N=271 M=41.06, SD=22.10 2nd (C)-N=284, M=41.10,SD=21.00 4th (T)-N=306, M=21.76,SD=10.71 4th (C)- N=449, M=20.33,SD=10.22 6th (T)-N=276, M=41.12, SD=19.67 6th (C)- N=279, M=39.32,SD= 20.80 Standardize Test 4th (T)-N=131, M=52.2, SD=9.8 4th (C)- N=186, M=48.5, SD=9.9 6th (T)-N=124, M=47.7, SD=9.7 6th (C)- N=158, M=51.8, SD= 9.8	MPP Quizes 2nd (T)-N=271, M=71.67, SD=23.01 2nd (C)-N=284, M=62.34, SD=22.44; 4th (T)-N=306, M=45.92, SD=22.38 4th (C)-N=449, M=31.80, SD=15.31 6th (T)-N=276, M=56.99, SD=22.44 6th (C)-N=279, M=49.14, SD= 22.08 Standardize Test 2nd (T)-N=119, M=48.7, SD=10.7 2nd (C)-N=137, M=51.1, SD=9.1; 4th (T)-				Teacher and Students Pre-post, cluster randomization, Treatment group/control	N, M, SD,	X

														N=131, M=52.2, SD=9.5 4th (C)- N=186, M=48.4, SD=10.0 6th (T)- N=124, M=48.4, SD=10.2 6th (C)- N=158, M=51.3, SD= 9.6						
37	Creemers, Kyriakides, and Antoniou	2013	Intergraded PD based on DIA-at University	X	X	2nd-6th				2nd-6th total n=2,356	1 year-8 sessions after school hours	Workshop and coaching			Effect sizes of DIA Teachers (ES Cohen's D) Stage 1=0.39 Stage 2=0.39 Stage 3=0.38 Stage 4=0.37 Whole sample=0.37			DIA vs HA- teacher and students	N, M, SD, T, ES	X-DIA Cohen's d per group of students taught by teachers situated at the same stage and for the whole sample.
39	McMeeking , Orsi, and Cobb	2012	CK and Ped summer workshops and follow up exper.	X	X	5th-8th	1 comparison Group-1317	2 Treatment Cohorts Group Group1-509 Group2-493	23 Math Teacher s		15 to 24 months PD program	workshop and others			Odds ratio estimate (all students)-1.29 [0.86, 1.93]- for 1 PD math vs. no courses; Odds ratio estimate (narrower sample)-1.38 [0.90, 2.11]- for 1 PD math vs. no courses; Odds ratio estimate (all students)-1.95 [1.37, 2.78]- for 2 or more PD math vs. no courses; Odds ratio estimate (narrower sample)-1.95 [1.35, 2.82]- for 2 or more PD math vs. no courses;			2 cohorts of student measures cohorts of teachers. Teacher treatment and control	N, SD, log odds, odd ratio	X-1 Comparis on group of students, 2 treatment cohorts groups of students- group1-1 PD math course, group 2 2 PD math courses, Teachers were held constant in study
44	Zwiep & Benken	2012	PD for Math and Science content	X														Pre-Post Student and Teachers	N, M, SD, Delta mean	X-No student outcomes.
49	Scher & O'Reilly	2009	CK, PCK, PD- meta Analysis	X	X						year round	Collaboration						Pre-Post, Treatment/ Control	N, ES	X-Studies are based on Research from 1990's- 2004 I was able to use only one research

																				article from this study-#80 it is dated for 2004.
50	Sheralyn Dash Raquel Magidin de Kramer Laura M. O'Dwyer Jessica Masters	2012	On Line PD 5th grade & Stud. Ach	X	X	5th-Students 1,435 Teachers -79	Control-790	Treatment-648	Teacher 45	Teacher 34	3 semesters-70 hours	workshop and others	Student Knowledge Test 5th grade pre-test 5th (T)-N=648, M=.42, SD=.16 5th (C)-N=790, M=.44, SD=.16	Student Knowledge Test 5th grade post-test 5th (T)-N=648, M=.54, SD=.21 5th (C)-N=790, M=.53, SD=.20		Teacher PCK Test 5th grade pre-test 5th PCK (T)-N=34, M=.46, SD=.14 5th PCK (C)-N=45, M=.45, SD=.11 5th PP (T)-N=34, M=2.52, SD=.35 5th PP (C)-N=45, M=2.71, SD=.37	Teacher PCK Test 5th grade post-test 5th PCK (T)-N=34, M=.58, SD=.14 5th PCK (C)-N=45, M=.44, SD=.12 5th PP (T)-N=34, M3.05, SD=.37 5th PP (C)-N=45, M=2.79, SD=.34	Corr Knowledge-Students Pre-Post, Randomly assign, Teacher Treatment/ Control Groups	R, M, SD, N	X
53	Bailey	2010	Sustained Standard Based PD 2nd & 3rd grade	X	X													Pre-Post Teacher and Student	N, M, SD	X-No student outcomes.
54	Harrisa, Stevens and Higgins	2011	Course 1 & 2 MS Teacher PD	X	X													Pre-Post-teachers ck growth	N, M, SD, T, F, df	X-No student outcomes.
56	Carey, Kleiman, Russell, Venable, & Louie	2008	Online PD-Compare Self pace to Facilatated	X	X													Teacher Treatment/ Control, Pre-Post	N, M, T, ES	X-No student outcomes.
58	Polly, Wang, McGee, Lambert, Martin, and David Pugalee	2014	Curriculum PD	X	X	K-5th grade students -688			Teacher -53, District A-32, District B-21		84 hours PD	Workshop and others			Student Ach mean gains (pretest-posttest) 1st Round (n=629), M=18.74 SD=30.59; 2nd Round (n=542), M=22.40, SD=31.51, 3rd Round (n=450), M=25.25, SD=30.30; Proportion of variance teacher level variable had on Student mean gains 1st-round ES= .55, 2nd-round ES=. 42, 3rd-round ES=.58			2 different school districts A and B Teachers and Students Pre-Posttest	N, M, SD, T, ES	X
59	Polly, Neale, & Pugalee	2014	Online PD-Math CurriculumTask Focus	X	X													Pre-Post Teacher	N, M, SD, T	X

63	Broyles	2009	Gateway Institute for Algebra PD-summer	X	X	9th-67 10th-31 Total-98	Foundation 2 9th grade Pair 1 N=13 M=517.2 SE=18.892 SD = 68.116 Pair 2 N=23 M=597.5 SE=10.384 SD = 49.800 Algebra 9th Grade Pair1 N=3 M=468.6 SE=16.166 SD = 28.00 Pair2 N=23 M=571.1 SE=8.884 SD = 42.606 Foundation 2 10th grade Pair 1 N=4 M=519.2 SE=7.933 SD = 15.866 Pair 2 N=7 M=614.9 SE=10.375 SD = 32.809 Algebra 10th Grade Pair1 N=4 M=498.2 SE=8.282 SD =16.584 Pair2 N=7 M=569.6 SE=10.831 SD =28.656	Foundations 2 9th Grade Pair1 N=3 M=589.7 SE=9.098; SD = 15.76 Pair 2 N=8 M=558 SE=6.88 SD = 19.46 Pair3 N=10 M=543.1 SE=11.62 SD =36.75 Pair 4 N=10 M=563.00 SE=10.591 SD = 33.492 Algebra 9th grade Pair 1 N=3 M=555.6 SE=7.783 SD = 13.481 Pair 2 N=8 M=532.0 SE=5.892 SD = 16.665 Pair 3 N=10 M=537.5 SE=9.938 SD = 31.427 Pair 4 N=10 M=527.8 SE=0.060 SD =0.190 Foundations 2 10th Grade Pair1 N=5 M=546.5 SE=9.270; SD = 20.728 Pair 2 N=7 M=547.8 SE=6.772 SD = 17.917 Pair3 N=5 M=523.6 SE=6.856 SD = 15.330 Pair 4 N=3 M=562.7 SE=8.611 SD = 14.915 Algebra 10th grade Pair 1 N=5 M=518.8 SE=9.678 SD = 21.641 Pair 2 N=7 M=537.9 SE=7.070 SD = 18.705 Pair 3	Teacher N=2	Teacher N=4	5 day Summer Gateway Institute for Algebra	Workshop only						Teacher Treatment/ control, Stud Ach. Foundation II Math vs Algebra	N, M, SE, F, Mean Diff, Mean square	X-Need Treatment /Control group informatio n

								N=5 M=530.1 SE=7.158 SD = 16.006 Pair 4 N=3 M=531.7 SE=8.990 SD = 15.571												
66	Allen (shared learning-no Ck Or PCK-pedagogy strategies)	2012	Impact PLC on 3rd grade-mixed methods-Collaboration	No	No-pedagogical knowledge	3rd grade-120 students; 6 third grade teachers -2 different schools	Control-60	Treatment-60			year round	Workshop & others-not sure if it is a workshop	Test P 1-PLC Group, N=60, 59.67, Std.= 22.453, Mean Diff=12.167 2-Non-PLC Group,N=60, Mean=47.50, Std.= 22.931, Mean Diff=12.167 Test A 1-PLC Group,N=60, Mean=48.95, Std.= 21.894, Mean Diff=7.283 2-Non-PLC Group,N=60, Mean=41.67, Std.= 14.748, Mean Diff=7.283 Test B 1-PLC Group, N=60, Mean=44.78, Std.= 16.435, Mean Diff=11.317 2-Non PLC Group,N=60, Mean=33.47, Std.= 15.027, Mean Diff=11.317					Treatment/ Control group-Students and Teachers (from 2 different schools)	N, M, SD, Mean diff, F,	Not sure, includes collaboration but does not focus on Ck and PCK
68	Wimberley	2013	Teacher Collaboration PD and Stud Ach. 8th grade		X-pedagogical strategies	8th Grade-50 collaborative schools districts and 50 Non-Collabor-ative schools districts	Control 50 Non Collaborative School Districts-students test scores	Control 50 Non Collaborative School Districts student scores			year round	Workshop others-			Non-Collabora-tive Student scores N=50, Mean 43.35, SD=11.11; Collabora-tive student scores N=50, Mean56.06, SD=7.83			Collaborative vs No Collaborative	N, M, SD, T	X-students' scores aggregated in Percentage of students scoring in the Proficient and Advance levels for Collaborative and Non Collaborative school districts
79	Fuerborne	2009	MS Math In-service Course-Content PD (Institute I & II)-6th-8th-5day	X	X													Pre-Post Teacher content test	N, M, SD, T	X

80	Van Haneghan, Pruet, and Bamberger	2004	Minoroity Schools (Project IMPACT PD) Ck & PCK, K-5th Math	X	X	2nd-153 5th-362	2nd (C)-41 5th (C)-85	2nd (T)- 153 5th (T)-277			3 year PD Project- MMI Summer Institute for 10 day	Workshop & Coaching	2nd Grade MMI Numeration- N=153, M=6.16, SD=0.94; Mental Math N=153, M=1.39, SD=0.99; Story Problem N=153, M=2.15, SD=1.17; Fractions N=153, M=2.70, SD=1.50; Geometry N=153, M=6.23, SD=1.41; 2nd Grade NO MMI Numeration N=41, M=6.05, SD=0.95; Mental Math N=41, M=1.17, SD=0.83; Story Problem N=41, M=1.83, SD=1.14; Fractions N=41, M=2.39, SD=1.50; Geometry N=41, M=6.22, SD=1.28;		2nd Grade ES=.16; 5th Grade ES=.66			Treatment/ control schools, Trained vs Untrained Teachers	N, M, SD, T	X
81	DiNardo	2010	Impact PLC PD on Stud Ach.- Mixed Methods- PK-5th grade- (3) 2 hour sessions		X	3rd gde- 54 5th gde- 67; Total 121; 6 teachers					(3) 2 hours PD =6 hours	Workshop & Coaching	3rd (OAS1), N=54, Mean=41.11, SD= 16.64; 5th (OAS1), N=67, Mean=44.12, SD= 11.72;	3rd (OAS2), N=54, Mean=48.80, SD= 15.75; 5th (OAS2), N=67, Mean=48.51, SD= 14.23;				Pre-Post Student	N, M, SD, SEM, T	X
82	Krupa	2011	Impact of Curricular PD (Core Plus) on Stud. Ach. Summer, follow-up	X	X	Algebra 1 IM N=569, Algebra 1 SS N=1,942; Algebra 2 IM N=290, Algebra 2 SS N=1,612;	Algebra 1 SS N=1,942; Algebra 2 SS N=1,612;	Algebra 1 IM N=569, Algebra 2 IM N=290,	Algebra 1 Teacher IM N=15; Algebra 2 Teacher IM N=8;	Algebra 1 Teacher SS N=21; Algebra 2 Teacher SS N=36	Core-Plus- (NCIM) Project PD- 4 Years- summer program (1 or 2 weeks), follow-up workshops, web support and monthly site	Workshop & Coaching		Algebra 1 IM, N=569, Mean=157.80, SD=9.63; Algebra 1 SS, N=1942, Mean=151.58, SD=8.53; Algebra 2 IM, N=290, Mean=148.83, SD=7.12; Algebra 2 SS, N=1612, Mean=151.17, SD=8.44;				Treatment Algebra IM/Control Algebra SS Students	N, M, SD, T, X2, HLM	X
83	Kuchey, Morrison & Geer	2009	ICS Program- Content and Pedagogy PD		X	1st-118 2nd-99 3rd-265	1st (C)-96 2nd (C)-55 3rd (C)-101	1st (T)-22 2nd (T)-44 3rd (T)-164			2 years PD	Workshop & others	Probability (T)- ICS 1st Grade N=22 M=69.9 SD=17.21 2nd Grade N=44 M=49.1 SD=14.91 3rd Grade N=164 M=47.0 SD=17.27 Probability (C) No ICS	Probability (T)-ICS 1st Grade N=22 M=89.5 SD=12.46 2nd Grade N=44 M=69.6 SD=23.12 3rd Grade N=164 M=70.8 SD=17.55 Probability (C) No ICS						

													1st Grade N=96 M=65.4 SD=17.33 2nd Grade N=55 M=58.7 SD=14.41 3rd Grade N=101 M=51.9 SD=19.20 Geometry (T)- ICS 1st Grade N=22 M=70.0 SD=21.11 2nd Grade N=44 M=45.9 SD=15.90 3rd Grade N=164 M=14.5 SD=7.87 Geometry (C) No ICS 1st Grade N=96 M=56.2 SD=17.97 2nd Grade N=55 M=55.8 SD=14.87 3rd Grade N=101 M=16.5 SD=9.95	1st Grade N=96 M=81.0 SD=19.68 2nd Grade N=55 M=73.6 SD=14.58 3rd Grade N=101 M=61.2 SD=18.14 Geometry (T)- ICS 1st Grade N=22 M=88.0 SD=14.41 2nd Grade N=44 M=57.5 SD=15.27 3rd Grade N=164 M=44.2 SD=19.58 Geometry (C) No ICS 1st Grade N=96 M=80.9 SD=15.35 2nd Grade N=55 M=62.7 SD=14.17 3rd Grade N=101 M=16.5 SD=15.23						
84	Phelan, Choi, Vendlinski, Baker & Herman	2011	Formative Assessment PD- Pedagogy PD	X	X			6th Grade- 4,091	6th Grade Betwee n (C)=633 6th Grade Within (C)=1,1 20	6th Grade Between (T)=842 6th Grade Within (T)=1,496	1 year PD	Workshop & others	6th Grade Between Control N=633 M=17.36 SD=4.79 6th Grade Between Treatment N=842 M=17.64 SD=4.84 6th Grade Within Control N=1,120 M=17.62 SD=4.36 6th Grade Within Treatment N=1,496 M=19.01 SD=4.24	6th Grade Between Control N=633 M=16.83 SD=5.51 6th Grade Between Treatment N=842 M=17.25 SD=6.37 6th Grade Within Control N=1,120 M=17.15 SD=5.38 6th Grade Within Treatment N=1,496 M=18.93 SD=6.12						

Total 31 studies-16 studies meet all requirements (student outcomes, N-Sample size, M-Mean, SD-Standard Deviation, Pre/Posttest or Treatment/Control Group)-15 studies did not meet requirements.

Appendix G-Quantitative Data Coding Matrix (16 Studies)

Paper No.	Authors	Year	Grade Level	Location	Duration	Content	Intervention	Sample Size Treatment (S)	Sample Size Control (S)	Student Treatment	Student Control	Student Post Score	Student Pre Score	Student Achievement Grains (Pre-Post)	Mean Difference=Post-Pre/Pooled SD (ES)
4	O'Dwyer, Masters, Dash, DeKramer, Humez and Russell	2010	5th & 8th	13 States (majority South and Northeast USA	D1	C3	W3	5th- 648 8th- 799	5th- 790 8th-1062					Pre to Post Scores 5th Grade Fract(T)- ΔM=.1735, SD=0.17, SD=0.24; Fract(C)- ΔM=0.139, SD=0.18, SD=0.25; Algebraic(T)- ΔM=0.114, SD=0.23, SD=0.25; Algebraic(C)- ΔM=0.078, SD=0.23,, SD=0.25; Measure (T)- ΔM=0.098, SD=0.20, SD=0.22; Measure(C)- ΔM=0.072, SD=0.20, SD=0.21 Overall 5th grade 5th (T)=ES=0.48, ΔM=0.127, SD=0.16, SD=0.21; 5th (C)=ES=0.36, ΔM=0.092, SD=0.16, SD=0.20 Pre to Post Scores 8th Grade Prop Reason(T)- ΔM=0.009, SD=0.15, SD=0.16; Prop Reason(C)- ΔM=0, SD=0.16, SD=0.16 Geom Meas(T)- ΔM=0.054, SD=0.19, SD=0.23; Geom Meas(C)- ΔM=0.041, SD=0.19, SD=0.22; Functions (T)- ΔM=0.094, SD=0.17, SD=0.17; Functions(C) ΔM=0.080, SD=0.17, SD=0.14; Overall 8th grade 8th (T)=ES=0.15, ΔM=0.029, SD=0.13, SD=0.14 8th (C)=ES=0.10, ΔM=0.019, SD=0.13, SD=0.14	ES=0.123, p≤0.001
18	McGatha, Bush, Rakes	2009	6th-8th	12 school districts USA	D2	C2	W3	6th-7 7th-6 8th-7	6th-87 7th-96 8th-138			6th (T)-N=98, M=13.204, SD=6.082 6th (C)-N=87,	6th (T)-N=98, M=13.143, SD=6.3098 6th (C)-N=87,		ES=-0.204, ns

												M=16.379, SD=6.695; 7th (T)-N=127, M=20.149, SD=5.515 7th (C)- N=96, M=17.313, SD=7.358; 8th (T)-N=109, M=19.716, SD=6.068 8th (C)-N=138, M=22.703, SD=5.981	M=13.207, SD=5.745; 7th (T)-N=127, M=12.677, SD=5.161 7th (C)- N=96, M=15.229, SD=6.339; 8th (T)-N=109, M=16.982, SD=6.308 8th (C)-N=138, M=19.029, SD=5.727		
20	Santagata, Kersting, and Stigler	2011	6th	Large School District USA	D2	C3	W2	Post Test N=2,564	Pre Test N=2,559			6th Quarterly Post-N=2,564, M=14, SD=7.17;	6th CST Pre Test - N=2,559, M=305.71, SD=62.29		ES=0.048, ns
26	Ross, Bruce, Hogaboam-Gray	2006	6th-106 Randomly Assigned teachers	Canada	D1	C3	W3	Motivation Variables Sept(1)N=406, Sept(2)N=408, Sept(3)N=408, Sept(4)N=408, Sept(5)N=406, Sept(6)N=408, Sept(7)N=408, Sept(8)N=407	Motivation Variables Jan(1) N=310, Jan (2)N=309, Jan (3)N=309, Jan (4)N=309, Jan (5)N=308, Jan(6)N,309, Jan(7)N=309, Jan(8)N=309;			Motivation Treatment Variables Sept(1) N=406, M=4.39, SD=0.85, Sept(2) N=408, M=4.41, SD=1.13, Sept(3)N=408, M=3.39, SD=1.30, Sept(4)N=408,M=2.85, SD=1.28, Sept(5)N=406,M=3.02, SD=1.16, Sept(6)N=408, M=5.01, SD=0.68 Sept(7)N=408,M=2.51, SD=1.11, Sept(8)N=407, M=4.79, SD=0.89 T-values (1) t=-1.640, df=714, p=0.101; (2) t=0.450, df=715, p=0.730; (3)t=-0.454, df=715, p=0.650; (4)t=-0.239, df=715, p=0.811; (5)t=0.461, df=712, p=0.645; (6)t=0.992, df=715, p=0.322; (7)t=1.566, df=715, p=0.118; (8)t=1.242, df=714, p=0.215;	Motivation Control Variables Jan(1) N=310, M=4.50, SD=0.88; Jan (2)N=309, M=4.38, SD=1.18, Jan (3)N=309, M=3.44, SD=1.29 Jan (4)N=309, M=2.87, SD=1.28, Jan (5)N=308, M=2.98, SD=1.16, Jan(6)N,309, M=4.96, SD=0.76, Jan(7)N=309, M=2.38, SD= 1.03, Jan(8)N=309; M=4.71, SD=0.89 Total Treatment Group received PD (May 2004) increased Student math ach increased from 2003 to 2004 on the EQAO Assessment ES=.10, t=(6105)=3.37, p<.001-small effect size		ES=0.013, ns

34	Telese	2012	8th Grade- randomly selected from NAEP 100 randomly selected	United States	D2	C1, C2, C3	W1, W2, W3			Large PD PD 1(T) N=596,287 M=278.63 SD=36.24; PD2(T) N=393,017 M=278.00 SD=36.49; PD3(T) N=1,501,197 M=279.98 SD=35.40; PD4(T) N=946,590 M=279.97 SD=36.17 PD5(T) N=898,936 M=278.63 SD=36.19; PD6(T) N=570,374 M=278.25 SD=36.41; PD7(T) N=482,301 M=280.55 SD=37.55; PD8(T) N=507,600 M=277.33 SD=36.43; PD9(T) N=260,479 M=272.14 SD=37.54; PD10(T) N=1,103,223 M=279.81 SD=35.12	No PD PD 1(C) N=365,583 M=280.73 SD=35.93; PD2(C) N=662,465 M=280.97 SD=35.38; PD3(C) N=167,091 M=277.61 SD=35.96 PD4(C) N=269,893 M=278.19 SD=35.84; PD5(C) N=260,416 M= 279.53 SD=35.68; PD6(C) N=536,594 M=282.02 SD=35.11; PD7(C) N=798,696 M=278.20 SD=35.15; PD8(C) N=478,616 M=280.80 SD=35.88; PD9(C) N=1,184,77 5 M=283.65 SD=34.69; PD10(C) N=384,499 M=282.77 SD=35.90				ES=-0.057, p≤0.001
36	Heller, Curtis, Rabe-Hesketh, Clarke, & Verbencoe ur	2007	2nd, 4th, 6th	5 Different School Districts Across USA	D1	C3	W3	MPPS Sample 2nd-271 4th-306 6th-276 Stand sample 2nd-119 4th-131 6th-124	MPPS Sample 2nd-284 4th-449 6th-279 Stand sample 2nd-137 4th-186 6th-158			MPP Quizzes 2nd (T)-N=271, M=71.67, SD=23.01 2nd (C)-N=284, M=62.34, SD=22.44; 4th (T)-N=306, M=45.92, SD=22.38 4th (C)- N=449, M=31.80, SD=15.31 6th (T)-N=276, M=56.99, SD=22.44 6th (C)- N=279, M=49.14, SD= 22.08 Standardize Test 2nd (T)-N=119, M=48.7, SD=10.7 2nd (C)-N=137, M=51.1, SD=9.1; 4th (T)-N=131,	MPP Quizzes 2nd (T)-N=271 M=41.06, SD=22.10 2nd (C)-N=284, M=41.10,SD=21.00 4th (T)-N=306, M=21.76,SD=10.71 4th (C)- N=449, M=20.33,SD=10.22 6th (T)-N=276, M=41.12, SD=19.67 6th (C)- N=279, M=39.32, SD= 20.80 Standardize Test 4th (T)-N=131, M=52.2, SD=9.8 4th (C)- N=186, M=48.5, SD=9.9 6th (T)-N=124, M=47.7, SD=9.7 6th (C)- N=158, M=51.8, SD= 9.8		ES=0.408, p≤0.001

												M=52.2, SD=9.5 4th (C)- N=186, M=48.4, SD=10.0 6th (T)-N=124, M=48.4, SD=10.2 6th (C)- N=158, M=51.3, SD= 9.6			
50	Dash, de Kramer, O'Dwyer, Masters & Russell	2012	5th-Students 1,435 Teachers-79	79 teachers from 12 States	D2	C3	W3	Treatment-648	Control-790			Student Knowledge Test 5th grade post-test 5th (T)-N=648, M=.54, SD=.21 5th (C)-N=790, M=.53, SD=.20	Student Knowledge Test 5th grade pre-test 5th (T)-N=648, M=.42, SD=.16 5th (C)-N=790, M=.44, SD=.16		ES=0.049, ns
58	Polly, Wang, McGee, Lambert, Martin & Pugalee	2014	K-5th grade students-688	2 School Districts in Southwestern States USA	D2	C3	W3							Student Ach mean gains (pretest-posttest) 1st Round (n=629), M=18.74 SD=30.59; 2nd Round (n=542), M=22.40, SD=31.51, 3rd Round (n=450), M=25.25, SD=30.30;	ES=0.142, p≤0.001
63	Broyles	2009	9th-67 10th-31 Total-98	5 High Schools in one District	D1	C2	W3			Foundations 2 9th Grade Pair1 N=3 M=589.7 SE=9.098; SD = 15.76 Pair 2 N=8 M=558 SE=6.88 SD = 19.46 Pair3 N=10 M=543.1 SE=11.62 SD =36.75 Pair 4 N=10 M=563.00 SE=10.591 SD = 33.492 Algebra 9th grade Pair 1 N=3 M=555.6 SE=7.783 SD = 13.481 Pair 2 N=8 M=532.0 SE=5.892 SD = 16.665	Foundation 2 9th grade Pair 1 N=13 M=517.2 SE=18.892 SD = 68.116 Pair 2 N=13 M=517.2 SE=18.892 SD=68.116 Pair 3 N=23 M=597.5 SE=10.384 SD=49.80 Pair 4 N=23 M=597.5 SE=10.384 SD=49.80 Algebra 9th Grade Pair1 N=3 M=468.6 SE=16.166 SD = 28.0 Pair2 N=3 M=468.6 SE=16.1668 SD = 28.0				ES=-0.450, p≤0.001

										Pair 3 N=10 M=537.5 SE=9.938 SD = 31.427 Pair 4 N=10 M=527.8 SE=0.060 SD =0.190 Foundations 2 10th Grade Pair1 N=5 M=546.5 SE=9.270; SD = 20.728 Pair 2 N=7 M=547.8 SE=6.772 SD = 17.917 Pair3 N=5 M=523.6 SE=6.856 SD = 15.330 Pair 4 N=3 M=562.7 SE=8.611 SD = 14.915 Algebra 10th grade Pair 1 N=5 M=518.8 SE=9.678 SD = 21.641 Pair 2 N=7 M=537.9 SE=7.070 SD = 18.705 Pair 3 N=5 M=530.1 SE=7.158 SD = 16.006 Pair 4 N=3 M=531.7 SE=8.990 SD = 15.571	Pair 3 N=23 M=571.1 SE=8.884 SD = 42.606 Pair 4 N=23 M=571.1 SE=8.884 SD =42.606 Foundation 2 10th grade Pair 1 N=4 M=519.2 SE=7.933 SD = 15.866 Pair 2 N=4 M=519.2 SE=7.933 SD = 15.866 Pair 3 N=7 M=614.9 SE=10.375 SD = 27.450 Pair 4 N=7 M=614.9 SE=10.375 SD = 27.450 Algebra 10th Grade Pair1 N=4 M=498.2 SE=8.282 SD =16.584 Pair2 N=4 M=498.2 SE=8.282 SD =16.564 Pair 3 N=7 M=569.6 SE=10.831 SD = 28.656 Pair 4 N=7 M=569.6 SE=10.831 SD = 28.656				
66	Allen	2012	3rd grade-120 students; 6 third grade teachers- 2 different schools	2 School in West Tennessee	D2	C2	W3	Treatment-60	Control-60				Test P 1-PLC Group, N=60, Mean=59.67, Std.= 22.453, Mean Diff=12.167 2-Non-PLC Group,N=60, Mean=47.50, Std.= 22.931,		ES=0.511, p≤0.001

													Mean Diff=12.167 Test A 1-PLC Group,N=60, Mean=48.95, Std.= 21.894, Mean Diff=7.283 2-Non-PLC Group,N=60, Mean=41.67, Std.= 14.748, Mean Diff=7.283 Test B 1-PLC Group, N=60, Mean=44.78, Std.= 16.435, Mean Diff=11.317 2-Non PLC Group,N=60, Mean=33.47, Std.= 15.027, Mean Diff=11.317		
68	Wimberley	2013	8th Grade-50 collaborative schools districts and 50 Non-Collabora-tive schools districts	100 Public Schools Districts in Missouri	D2	C3	W3	Contol 50 Non Collaborative School Districts student scores	Contol 50 Non Collaborative School Districts-students test scores	Collaborative student scores N=50, Mean=56.06, SD=7.83	Non-Collaborative Student scores N=50, Mean 43.35, SD=11.11;				ES=1.322, p≤0.001
80	Van Haneghan, Pruit, and Bambert	2009	2nd-153 5th-362	Elementary Urban Schools in the South	D3	C3	W2	2nd (T)- 153 5th (T)-91 5th (T)-277	2nd (C)-41 5th (C)-26 5th (C)-85				2nd Grade MMI Numeration- N=153, M=6.16, SD=0.94; Mental Math N=153, M=1.39, SD=0.99; Story Problem N=153, M=2.15, SD=1.17; Fractions N=153, M=2.70, SD=1.50; Geometry N=153, M=6.23, SD=1.41; 2nd Grade NO MMI Numeration N=41, M=6.05, SD=0.95; Mental Math N=41, M=1.17, SD=0.83; Story Problem N=41, M=1.83, SD=1.14; Fractions N=41, M=2.39, SD=1.50; Geometry N=41, M=6.22, SD=1.28;		ES=0.229, p≤0.001

													5th Grade MMI Numeration-N=91, M=2.80, SD=0.96; Mental Math N=91, M=5.81, SD=2.27; Story Problem N=91, M=1.38, SD=1.12; Fractions N=91, M=1.19, SD=1.00; 5th Grade NO MMI Numeration N=26, M=2.42, SD=1.24; Mental Math N=26, M=4.77, SD=1.75; Story Problem N=26, M=0.81, SD=1.06; Fractions N=26, M=0.50, SD=0.71; 5th Grade TIMSS (MMI) N=289, M=7.04, SD=2.71; 5th Grade TIMSS (NO MMI) N=91, M=5.08, SD=2.49		
81	DiNardo	2010	3rd gde- 54 5th gde- 67; Total 121; 6 teachers	Southeastern USA	D1	C2	W2					3rd (OAS2), N=54, Mean=48.80, SD= 15.75; 5th (OAS2), N=67, Mean=48.51, SD= 14.23;	3rd (OAS1), N=54, Mean=41.11, SD= 16.64; 5th (OAS1), N=67, Mean=44.12, SD= 11.72;		ES=0.466, p≤0.001
82	Krupa	2011	Algebra 1 IM N=569, Algebra 1 SS N=1,942; Algebra 2 IM N=290, Algebra 2 SS N=1,612;	North Carolina	D3	C3	W2	Algebra 1 IM N=569, Algebra 2 IM N=290,	Algebra 1 SS N=1,942; Algebra 2 SS N=1,612;			Algebra 1 IM, N=569, Mean=157.80, SD=9.63; Algebra 1 SS, N=1942, Mean=151.58, SD=8.53; Algebra 2 IM, N=290, Mean=148.83, SD=7.12; Algebra 2 SS, N=1612, Mean=151.17, SD=8.44;			ES=0.385, p≤0.001

83	Kuchey, Morrison & Geer	2009	1st, 2nd & 3rd	Midwestern City	D3	C3	W3	1st (T)-22 2nd (T)-44 3rd (T)-164	1st (C)-96 2nd (C)-55 3rd (C)-101			Probability (T)-ICS 1st Grade N=22 M=89.5 SD=12.46 2nd Grade N=44 M=69.6 SD=23.12 3rd Grade N=164 M=70.8 SD=17.55 Probability (C) No ICS 1st Grade N=96 M=81.0 SD=19.68 2nd Grade N=55 M=73.6 SD=14.58 3rd Grade N=101 M=61.2 SD=18.14 Geometry (T)- ICS 1st Grade N=22 M=88.0 SD=14.41 2nd Grade N=44 M=57.5 SD=15.27 3rd Grade N=164 M=44.2 SD=19.58 Geometry (C) No ICS 1st Grade N=96 M=80.9 SD=15.35 2nd Grade N=55 M=62.7 SD=14.17 3rd Grade N=101 M=16.5 SD=15.23	Probability (T)-ICS 1st Grade N=22 M=69.9 SD=17.21 2nd Grade N=44 M=49.1 SD=14.91 3rd Grade N=164 M=47.0 SD=17.27 Probability (C) No ICS 1st Grade N=96 M=65.4 SD=17.33 2nd Grade N=55 M=58.7 SD=14.41 3rd Grade N=101 M=51.9 SD=19.20 Geometry (T)- ICS 1st Grade N=22 M=70.0 SD=21.11 2nd Grade N=44 M=45.9 SD=15.90 3rd Grade N=164 M=14.5 SD=7.87 Geometry (C) No ICS 1st Grade N=96 M=56.2 SD=17.97 2nd Grade N=55 M=55.8 SD=14.87 3rd Grade N=101 M=16.5 SD=9.95		ES=0.014, ns

84	Phelan, Choi, Vendlinski, Baker & Herman	2011	6th Grade	7 Different School districts	D2	C1	W3	6th Grade Between (T)=842 6th Grade Within (T)=1,496	6th Grade Between (C)=633 6th Grade Within (C)=1,120			6th Grade Between (C) N=633 M=16.83 SD=5.51 6th Grade Between (T) N=842 M=17.25 SD=6.37 6th Grade Within (C) N=1,120 M=17.15 SD=5.38 6th Grade Within (T) N=1,496 M=18.93 SD=6.12	6th Grade Between (C) N=633 M=17.36 SD=4.79 6th Grade Between (T) N=842 M=17.64 SD=4.84 6th Grade Within (C) N=1,120 M=17.62 SD=4.36 6th Grade Within (T) N=1,496 M=19.01 SD=4.24		ES=0.218, p≤0.001

Final 16 studies meet all requirements (student outcomes, N-Sample Size, M-Mean, SD-Standard Deviation-Pre/Posttest or Treatment/Control Group)-15 out of 31 studies did not meet all requirements.

Appendix H-Professional Development Categories

	Study Categories					
	Professional learning Community (PLC)	Formative Assessment PD	Curriculum PD	On-Line PD	Initiated Math PD	Large Scale PD
	26	18	36	4	80	34
	66	84	58	20	83	
	68		63	50		
	81		82			
Total	4	2	4	3	2	1

Appendix I-PD Categories (Duration, Content, and Intervention)

No.	Study	ES (d)	PLC	Form	Curr	On-line	initiated	Large	Duration	Content	Intervention
66	Allen (2012)	0.511***	X						D2	C2	W3
63	Broyles (2009)	-0.450***			X				D1	C2	W3
50	Dash (2012)	0.049				X			D2	C3	W3
81	DiNardo (2010)	0.466***	X						D1	C2	W2
36	Heller (2007)	0.408***			X				D1	C3	W3
82	Krupa (2011)	0.385***			X				D3	C3	W2
83	Kuchey (2009)	0.014					X		D3	C3	W3
18	McGatha (2009)	-0.204**		X					D2	C2	W3
4	O'Dwyer (2010)	0.123***				X			D1	C3	W3
84	Phelan (2011)	0.218***		X					D2	C1	W3
58	Polly (2014)	0.142***			X				D2	C3	W3
26	Ross (2006)	0.013	X						D1	C3	W3
20	Santagata (2011)	0.048				X			D2	C3	W2
34	Tesele (2012)	-0.057***						X	D2	C3	W3
80	Van Haneghan (2009)	0.229***					X		D3	C3	W2
68	Wimberley (2013)	1.322***	X						D2	C3	W3

Table Key

Yellow- Favors Treatment Group
Red-Favors Control Group
No Color- Not significant

Initiated-Reform Initiated PD
Large-Large Scale PD

D1-short term; D2-1 academic year; and D3-multiple years
C1-content only; C2-pedagogy only; C3-content and pedagogy
W1-workshop only; W2-workshop plus coaching; W3-workshop plus other support