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PROFESSIONAL DEVELOPMENT FOR HIGH SCHOOL TEACHERS: AN INVESTIGATION OF ITS EFFECT ON STUDENT ACHIEVEMENT AND LONG TERM EFFECT ON TEACHER KNOWLEDGE AND PRACTICE

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Professional development for high school teachers: An investigation of its effect on student achievement and long-term effect on teacher knowledge and practice

by

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Dedication

This dissertation is dedicated to my late Mother, Patricia L. Meyer, who impressed on me the importance of excelling in education and to my husband John M. Vega for always encouraging, supporting, and propelling me to pursue and finish my goals.

Acknowledgements

I would like to take this opportunity to express my appreciation to the many people who have supported me in this project and have brought me thus far in my education. First of all, to Dr. Delgado, who agreed to be the Chair of my committee and who has helped direct, critique, and develop me throughout, I am grateful. I also appreciate Dr. Marshall, Dr. Barufaldi, Dr. Empson and Dr. Travis for serving on my committee, supplying input and advice. Special thanks to Dr. Travis for sharing PD data and contact information on the teachers, as well as being my mentor and guide for many years. I appreciate all the high school teachers who gave permission to be interviewed and observed. I am also thankful for my husband, John, who has always supported and believed in me, and for my children, Nathaniel, Nicole, Solomon, and Elizabeth who let "Mommy" study. I could not have completed this work without the help of my family and friends in support, prayer, and help with watching the new baby Elizabeth, born during my dissertation. In addition, I want to thank my late Mother, Patricia L. Meyer, whose love for learning brought me to this place in my life. Most importantly, I want to thank God for giving me the ability to accomplish all things.

Professional development for high school teachers: An investigation of its effect on student achievement and long-term effect on teacher knowledge and practice

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Intuitively, providing teachers with high-quality professional development that focuses on research-based strategies should improve teacher practice that in turn would positively affect student outcomes. Displaying and translating this pathway is much harder than it seems. Even though there are recommendations in abundance for high-quality teacher professional development to be provided in order to meet ambitious reforms (i.e. National Council of Teachers of Mathematics, 2000; "No Child Left Behind Act," 2001), “we are only beginning to learn…exactly what and how teachers learn from professional development, or about the impact of teacher change on student outcomes” (Borko, 2004, p. 3).

The purpose of this dissertation was to investigate the effects and longevity of professional development (PD) on secondary mathematics teachers’ knowledge and

practice while investigating student achievement. This research was intended to further the field by providing a description of changes in teacher knowledge and practice as a result of PD of high school teachers looking for plausible links that could influence student achievement therefore working to establish "links among professional development, teacher learning and practice and student learning" (Yoon et al., 2007, p. 3). This investigation utilized teacher and student data from the program years, as well as data collected two years after the professional development, providing a unique look at the longevity of effects on the teachers.

This results from this dissertation demonstrated the longevity of changes in teachers from the PD, a need for PD research according to Kazemi and Hubbard (2008). Indeed, teacher knowledge and practice changed from the PD according to the data and the effect of the PD continued and/or expanded in many teachers. The change in teachers' practice and knowledge during the PD, however, was not found to have significantly affected student achievement.

Additionally, data from this dissertation supported the idea in prior literature that content, active learning, collaboration, and leadership are key components of long-term, effective PD. It further revealed the interconnections between the theoretical framework pieces describing ways teachers learn and develop from PD experiences.

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Chapter One: Introduction

> Although there is substantial evidence that high-quality professional development can improve teacher practices, less evidence exists for the effects of teacher professional development on the intermediate outcomes, such as teacher practices, and their ultimate effects on K-12 student achievement. (Wallace, 2009, p. 576)

> Showing that professional development translates into gains in student achievement poses tremendous challenges, despite an intuitive and logical connection. (Yoon, Duncan, Lee, Scarloss, & Shapley, 2007, p. 3)

Intuitively, providing teachers with high-quality professional development that focuses on research-based strategies should improve teacher practice that in turn would positively affect student outcomes. Demonstrating and translating this pathway is much harder than it seems. Although there are recommendations in abundance for high-quality teacher professional development to be provided in order to meet ambitious reforms (i.e. National Council of Teachers of Mathematics, 2000; "No Child Left Behind Act," 2001), "we are only beginning to learn…exactly what and how teachers learn from professional development, or about the impact of teacher change on student outcomes" (Borko, 2004, p. 3).

Teacher knowledge is an extremely important influence on what happens in classrooms (Fennema & Franke, 1992, p. 147) and has been found to positively affect student's mathematics learning by a similar effect size as the student's background (Hill, Rowan, & Ball, 2005, p. 396). Additionally, in review of specific studies focused on finding teacher effects on student achievement, McCaffrey and colleagues (2003) found "teacher effects matter" and these effects carry into the students' academic future (p. 35). Effective teachers deeply understand the mathematics to be taught with flexibility in practice (National Council of Teachers of Mathematics, 2000, Chapter 2, The Teaching Principle section). The practice of teachers exhibits knowledge, both content and pedagogical, in action. Classroom practice is where teachers synthesize this knowledge "into a cohesive lesson that students can understand" (Wallace, 2009, p. 580). With this importance of teacher knowledge in mind, careful consideration of the way professional development can influence the improvement of teacher knowledge should be a prominent focus of professional development research.

This study examined professional development's effect on teacher knowledge and practice while looking at how these affect student achievement. Studies that investigate teacher change in knowledge and practice from professional development and link those changes to increased student achievement have been done mainly at the elementary level (Yoon et al., 2007). Also, teacher's growth in professional development, in addition to the long-term influence of the professional development on the practice of teachers, has

not been well documented (Kazemi & Hubbard, 2008, p. 432). Therefore, this study addresses these main areas.

PURPOSE

The purpose of this dissertation was to investigate the effects and longevity of professional development (PD) on secondary mathematics teachers' knowledge and practice while investigating student achievement. Specifically the dissertation study was guided by the following research questions:

1. How did student achievement change, if it all, for two schools where all the Algebra I and Algebra II teachers participated in a PD program with all the characteristics of effectiveness when compared to similarly matched schools with no participation?

2. What changes in teacher knowledge and changes in their perception of practice resulted from participating in this PD program?

3. What long-term changes are evident in teachers' practice from this PD and how do these compare to the changes during the program?

This research will further the field by providing a description of changes in teacher knowledge and practice as a result of PD of high-school teachers looking for plausible links that could influence student achievement, therefore working to establish "links

among PD, teacher learning and practice and student learning" as recommended by Yoon et al. (2007, p. 3), who found studies that meet evidence standards linking teacher knowledge and change from PD to student achievement gains only at the elementary level. Additionally, this study provides a unique look at the longevity of the PD's effect because of the situative nature of the investigation two years after the program. This provides a big picture look at PD's influence on teacher knowledge and practice for a five-year period, presenting long-term evidence as recommended by Kazemi and Hubbard (2008). The long-term changes in practice described in this study will inform designers of PD in providing evidence of teacher change that seems to be long lasting and describe the evolving nature of teacher learning from effective PD. This would aid researchers and developers to perhaps change certain elements of PD that do not seem to show longevity in teacher practice and know what elements do show long-term change in teachers.

Additionally, increases in student achievement through teacher change in PD is desirable, but closing gaps in achievement of students is also important (Steen, 2003). Therefore this research was conducted in a setting that could shed light on closing gaps. In high-poverty areas where minorities usually live there are a greater number of teachers who are novices or teaching without certification (Kitchen, 2005; Lee & Buxton, 2010; Texas Legislative Study Group, 2011; Vega & Travis, 2012). Understandably, closing the gap in performance for minority and high-poverty students is even harder when under-

qualified teachers are prevalent. Even with the No Child Left Behind legislation (2001), some students get left behind. Therefore, this dissertation study investigated PD's long-term effect on teachers who serve a high minority and high poverty student population.

CONCEPTUAL FRAMEWORK

Effective PD has been found to have several important characteristics, that is, it must provide long term opportunities that are centered on content, be coherent, promote active learning, be collaborative, and foster leadership, according to research reviewed below. These elements impact teacher knowledge and practice, which then can provide more opportunities for greater student achievement. Additionally, PD should be provided over longer periods of time as this provides a greater opportunity of impacting teacher practice (Garet et al., 2001; Ostermeier, Prenzel, & Duit, 2010). Each of these elements is reviewed below.

Content.

One of the characteristics of effective PD is for its tasks to be centered on content that is directly related to what is taught to students. (Borko, 2004; Fishman & Davis, 2006; Garet et al., 2001; Higgins & Parsons, 2009; Kazemi & Hubbard, 2008; Loucks-Horsley, Stiles, Mundry, Love, & Hewson, 2010). The content focus not only helps teachers develop deeper knowledge of the subject but also provides opportunities for

teachers to be engaged in thinking and learning about the way students learn this content, that is, deepening PCK.

Coherence.

According to research done by Garet and colleagues (2001) PD should provide opportunities for teachers to have hands-on experience that is content focused and coherent to what happens daily in schools. Coherence is found when the PD is relevant to the daily needs of teachers such as being based on current standards and assessments, and enabling teachers to see connections to what is actually done in classrooms.

Active learning.

Additionally, PD should allow teachers to actively participate in enhancing their own knowledge (Loucks-Horsley et al., 2010; Wilson & Berne, 1999) as this is key to how people acquire knowledge and learn and is consistent with reform based learning (Bransford, Brown, & Cocking, 2000).

Collaboration.

Collaborative learning is another effective feature of PD because it promotes professional discourse regarding student learning of specific topics and an overall increase in teacher understanding as well as support for newly learned practices (Borko, 2004; Garet et al., 2001; Loucks-Horsley et al., 2010; Ostermeier et al., 2010).

Fostering leadership.

Encouraging and providing opportunities for teachers to serve in roles of leadership is another important characteristic of effective PD (Darling-Hammond, Bullmaster, & Cobb, 1995; Loucks-Horsley et al., 2010). Leadership can be serving in a titled position, or simply helping to promote confidence and professionalism in teaching. Teachers could, for example, initiate the sharing of lesson plans or mentor other less experienced teachers.

Long-term.

Furthermore, effective PD is provided over a long period of time, according to research. When PD is "sustained and intensive" (Garet et al., 2001, p. 935) it has more of a chance of impacting teacher practice than PD that is shorter in duration. Ostermeier et al. (2010) advocates "a long-term approach of PD with a significant focus on classroom teaching instead of a one-shot attempt" (p. 310). PD should be an ongoing effort for teachers where there is time for practice, planning and working with peers (Schoenfeld, 2002).

Summary.

Programs that are "characterized by coherence, active learning, sufficient duration, collective participation, a focus on content knowledge, and a reform rather than traditional approach" are in short supply (Yoon et al., 2007, p. 1). As described above,

effective PD opportunities are long-term and have teachers collectively and actively learning content that is relevant to their teaching experience, that is coherent, and encourage and develop leadership. Effective PD provides a long-term, content based, coherent, active learning, collaborative, leadership-driven opportunity for teachers.

METHODOLOGY

This study reports on an effort to aid the teachers currently in high minority secondary schools in South Texas. The PD program in this study, which this researcher took part in during previous years as a practicing teacher, was designed to build confidence in knowledge of the standards of the state. The teachers were provided opportunities to actively engage in content related tasks, collaboratively. The PD was approximately three years in length, hence long-term, and consisted of summer institutes and sessions throughout the academic year fostering teacher mathematical and PCK (Shulman, 1987) through hands-on activities and collaboration. In particular, this reform-oriented PD program was aimed at promoting teachers' confidence in teaching standards-aligned content, thereby promoting coherence for the teachers. This was done through encouraging increased student participation, exploration, and knowledge construction; nurturing teachers' use of manipulatives and technology; and building teacher leadership through conference presentations and opportunities in the program itself. The PD program, therefore, had all the elements of effectiveness as defined by research in that it was long-term, content centered, coherent, promoted active learning, while utilizing

collaboration, and fostering leadership. By studying a PD program that embodies the key elements of effectiveness, this dissertation is more likely to detect teacher change and possibly be able to trace this change to improvement in student achievement.

The program had participants from ten different schools, representing three South Texas districts. Two specific high schools were chosen for study in this dissertation because all the teachers of Algebra I and Algebra II participated in the PD; school-level data were available, and therefore these schools could be used to assess the impact of PD on student achievement. Another four schools with analogous demographics but no teacher participation were selected as a comparison group. The schools are similar in that they have over a 95% minority student population and over 82% economically disadvantaged student population (students who qualify for free or reduced lunch).

In order to address Research Question One regarding student achievement changes during the PD, state assessment data from the Texas Assessment of Knowledge and Skills (TAKS), the statewide-standardized test used for accountability, was used for the two schools whose teachers participated in the program. These data are reported in a form of percentage of students that meet the State objectives or standards and was retrieved for two years before the PD and the years of the PD. Additionally, data from the same years of four comparison schools, whose teachers were not involved in this PD, were also retrieved and used as control schools in this study.

Regarding Research Question Two, teacher change in knowledge and perceived

practice during the PD, the data analyzed consisted of teachers' reflections written during the PD, interviews that took place two years after the program, and teachers' pre/post assessment results on their content knowledge and PCK. In order to analyze the teachers' reflections and interview data, a grounded theory analysis (Corbin & Strauss, 2008) was carried out, and the conceptual framework was utilized to structure the analysis. The teacher assessment data was statistically tested as well, using a dependent t-test.

In order to address Research Question Three, teachers' long-term changes in knowledge and practice, participants from the PD were interviewed and observed two years after the program. During observations detailed field notes were procured in order to provide triangulation with the teachers' self reported data in the interviews. These data were compared to their reflections on their practice collected during the PD following a grounded theory approach (Corbin & Strauss, 2008)

LIMITATIONS

This study has limitations in that the long-term PD has already taken place and a description of teacher knowledge and changes in practice during the PD will have to rely on teacher self-reported data available through written reflections and other artifactual data from the PD. The self-reported nature of some of the data may show some form of "self-presentation bias or social desirability bias", the tendency for people to present themselves favorably (Kopcha & Sullivan, 2007, p. 628). However, this researcher

attended this PD as a teacher at a previous time and this can provide insight into teacher change in knowledge and practice indicated by the data.

Additionally, student achievement data were not available by teacher, only by school, so a unique teacher's effect could not be studied. There are multiple potential reasons for increases in student achievement as measured by percentage passing rate and this study cannot control for all of them. However, this study identified four other schools with similar minority and economic status in the same urban area to use as control schools in order to compare the student data from the schools with teachers who attended the PD, in an attempt to rule out most external factors beyond the PD. Due to the small number of schools being compared (n=6, 2 PD schools and 4 non-PD) statistical procedures could not be carried out, only descriptive statistics.

OVERVIEW

The next chapter of this dissertation will provide theoretical background regarding PD research. Chapter three will then discuss the design of this project, methodology, collection of data, and methods of analysis. The results of the study are found in chapter four. Finally, chapter five provides interpretations of the findings and discussion of implications for the mathematics education community.

Chapter Two: *Literature review*

This chapter will first discuss literature relevant to this dissertation beginning with a discussion on minority gaps in education, setting out the importance of teacher knowledge and background, as well as the lack of qualified teachers for some students. Then, the elements of effective PD will be described and utilized as a theoretical framework. Next will be a section examining how teacher learning in PD has affected student achievement, with a review of research on PD for secondary teachers to follow. Finally, research on the long-term effect of PD on teachers will be discussed to conclude this chapter.

CONTINUED MINORITY GAP IN STUDENT ACHIEVEMENT

When a *Nation at Risk* (1983) warned of the lack in prepared students in the United States, the nation worked hard in bringing about changes to the education of the nation with standards-based instruction in order to bridge gaps in achievement. However, even though students from differing racial groups take higher-level coursework in mathematics, student performance still exhibits gaps persistent along racial and ethnic lines (Steen, 2003). While scores increased, according to a report for the National Center for Education Statistics (Vannerman, Hamilton, Anderson, & Rahman, 2009), evidence seems to point to a continued divide between black and white students in mathematics with an achievement gap of twenty-three points on the National Assessment of

Educational Progress (NAEP) at age 9, and a twenty-six point gap at age 13, and that gap being more narrow than in 1978 yet not significantly different than the gap found in 1999. Regarding gaps in mathematics on the NAEP between Hispanic and non-Hispanic White students, while both increased their scores, the gap was not significantly different from 1990 to 2009 at grades 4 or 8. In fact in 2009 the gap in 4th grade was twenty-one points - the same as in 2007, and in 8th grade twenty-six points (Hemphill, Vannerman, & Rahman, 2011).

Research shows that students who attend schools from affluent neighborhoods are presented with higher quality opportunities in education than those students who are from communities with higher rates of poverty (i.e. Kitchen, 2005; Valencia, 2010). Simply put, "those with 'better' property are entitled to 'better' schools" and this property includes curriculum as well (Ladson-Billings & Tate, 1994, p. 54). Children in communities of poverty receive rote instruction instead of lessons involving high-level or critical thinking skills (Kitchen, 2005). In high-poverty areas where minorities usually live, there is a greater proportion of teachers who are novices or teaching without certification (Kitchen, 2005; Lee & Buxton, 2010; Texas Legislative Study Group, 2011; Vega & Travis, 2012). These issues make equity in education even more difficult.

There is a common theme that schools with large populations of minorities and those with issues of poverty have the most teachers lacking background or certification (EdTrust, 2008; Lee & Buxton, 2010; National Science Foundation, 2012). This "lack of

qualified teachers and resources continues to plague high poverty schools despite research showing that a teacher's understandings of subject matter knowledge and pedagogical strategies needed to teach that subject matter knowledge influences how well children learn" (Barton, 1998, p. 527) This results in these students not having the same opportunities to learn as others in wealthier school districts with more knowledgeable teachers. Kahle (1996, p. 3) describes one definition of equity to be "the same treatment for everyone so that all students have an equal chance to meet the same standards and an equal opportunity to master those standards". Furthermore, Ladson-Billings and Tate (1994) refer to "curriculum" as a type of "intellectual property" that varies in "quality and quantity" depending on the "property values of the school" (p. 54). "Curriculum" refers not only to books and materials, but is also influenced by teachers' content and pedagogical knowledge. Essentially, high-poverty schools are more likely to have teachers that are less qualified therefore, students in these schools do not have the same opportunities to rise to the high standards in mathematics today. An equitable education for all students includes providing well-prepared teachers (NCTM, 2000). Effective PD such as what was provided to the teachers in this study can help build knowledge providing a more equitable education.

TEACHER KNOWLEDGE AND PRACTICE

Researchers agree, "what a teacher knows is one of the most important influences on what is done in classrooms and ultimately on what students learn" (Fennema &

Franke, 1992, p. 147). In a recent report, experts recognized that sometimes STEM teachers of grades K-12 are lacking in content knowledge that affects their teaching these subjects effectively (United States Accountability Office, 2014). The National Council of Teachers of Mathematics' Principles & Standards (2000) suggest, "To be effective, teachers must know and understand deeply the mathematics they are teaching and be able to draw on that knowledge with flexibility in their teaching tasks." (Chapter 2, The Teaching Principle section) Interestingly, teacher knowledge was found to affect the learning of students positively by the same effect size as the background of students (Hill et al., 2005, p. 396). This importance of teacher knowledge leads to a focus of the ways PD can influence and improve the knowledge of teachers. Borko (2004) states, "research provides evidence that intensive PD programs can help teachers to increase their knowledge and change their instructional practices" (p. 5). In particular, schools with teachers who attended long-term PD were found to have lower-track students benefit even more in "the improvement of student competencies and the increase of interest and motivation" (Ostermeier et al., 2010, p. 320).

Teaching is a complex process with a necessary knowledge base. Important features of this base that is dependent on content were first outlined by Shulman (1987), namely:

> (1) scholarship in content disciplines, (2) the materials and settings of the institutionalized educational process…, (3) research on schooling, social

> organizations, human learning, teaching and development, and the other social and cultural phenomena that affect what teachers can do, (4) and the wisdom of practice itself. (p. 8)

Where content and pedagogy intersect provides the distinguishing factor for this knowledge base (Shulman, 1987); essentially, teacher effectiveness is found not only in teacher knowledge but the use of that knowledge in classrooms (Hill et al., 2005). This specialized knowledge for teaching is called pedagogical content knowledge (PCK), and it represents teachers' "understanding of how particular topics, problems, or issues are organized, represented, and adapted to the diverse interests and abilities of learners, and presented for instruction" (Shulman, 1987, p. 8). Ball and colleagues (2008; Hill et al., 2008) have further expounded on this work to develop the concept of "mathematical knowledge for teaching" (MKT) that actually is separated into two parts: PCK and subject matter knowledge (SMK). This theory has been further developed to include parts to describe the differing types of knowledge teacher's use.

TEACHER BACKGROUND

Teacher background is important to consider for the learning of teachers in PD. "There is a growing recognition that teachers, like their students, bring with them experiences and prior understandings that profoundly shape their learning." (Ball, 1996, p. 504) Teachers come with ideas from their own educational experience of what schooling is like, often defaulting "to the way they were taught when they were students"

(Wallace, 2009, p. 575). Also, "many teachers have spent an entire career mastering the skills required for an instructionist classroom" and are not aware of advances in understanding of learning and the way it best occurs, and struggle with envisioning a school where conceptual understanding, building on prior knowledge, the creation of learning environments, and reflection is emphasized (Sawyer, 2006, p. 3). For example, teachers may not have experienced reformed, sense-making ways of learning and this can affect the way they receive PD activities or even put into practice the ideas from the PD. Loucks-Horsley et al. (2010) explains, "they learned by memorizing information and others' explanations through a transmission model. These experiences served as powerful models for their own teaching and created a script that they followed in their own teaching." (p. 76) Teachers may not have had the experience of seeing knowledge as something that can be reasoned or questioned but instead see knowledge as just facts to be memorized (Ball, 1996). Basically, the core of education must change with reform-based teaching (Carpenter & Franke, 2004). Ball (1996) explains:

> What teachers bring to the process of learning to teach affects what they learn. Increasingly, teachers' own personal and professional histories are thought to play an important role in determining what they learn from professional development experiences….There is as much to unlearn as there is to learn…the odyssey probably entails revising deeply held notions about learning and knowledge. (p. 501).

In addition to previous educational experiences, teachers' professional education may cause challenges to learning in PD such as methods or content courses (Wilson & Berne, 1999). Some teachers come to the profession without adequate subject-matter knowledge or training that hinders their practices. In mathematics, for example, the choice of problems that are generative and ways of being supportive throughout student learning and interpretation of student responses can be challenging without appropriate mathematical knowledge resources (Ball, 1996). Some teachers' background is lacking in certification as well.

EFFECTIVE PD, A THEORETICAL FRAMEWORK

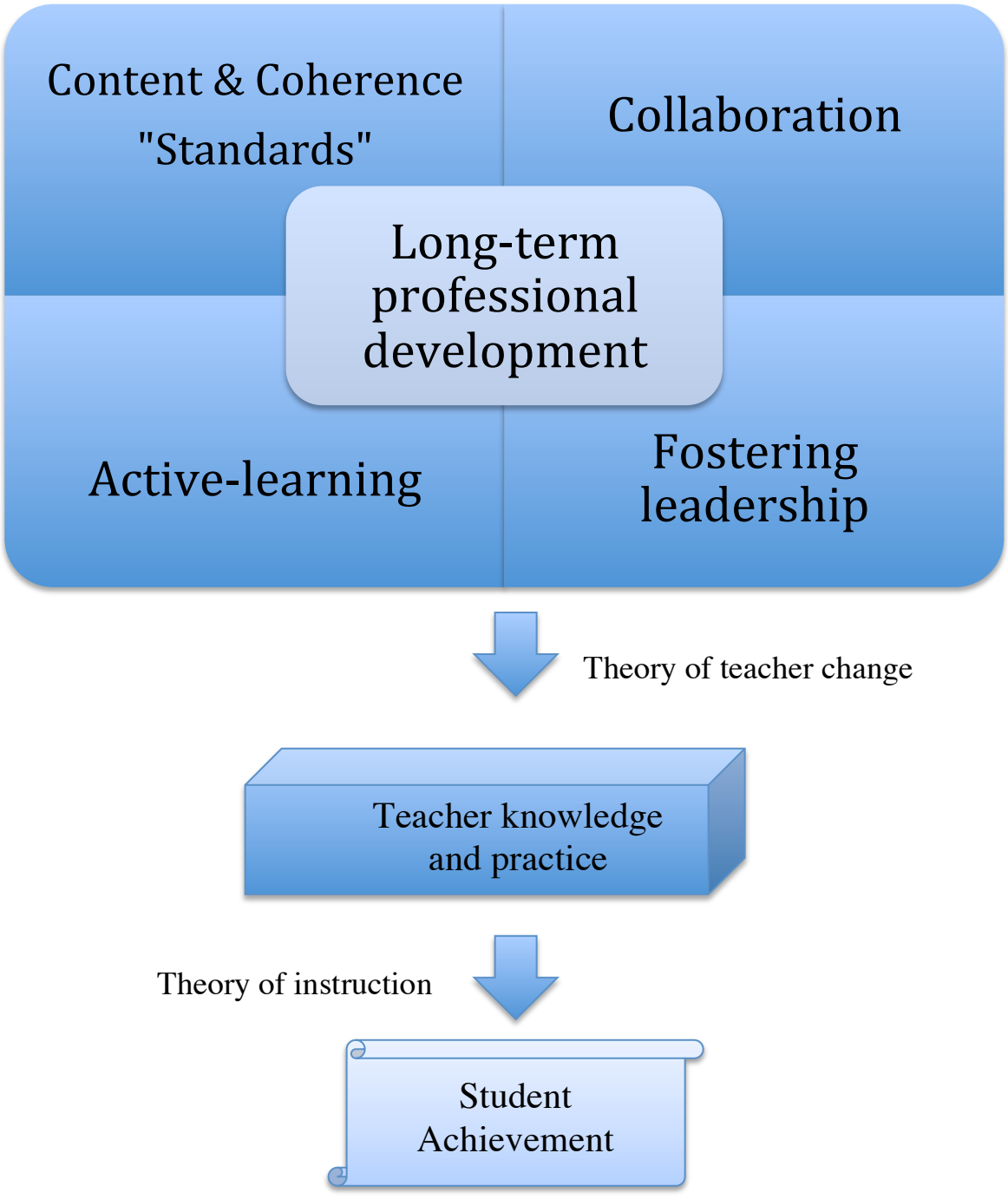
In order to gather an overview regarding research on PD several review articles and other comprehensive works were consulted, that is Garet et al. (2001), Yoon et al. (2007), and the text "Designing Professional Development for Teachers of Science and Mathematics" by Loucks-Horsley et al. (2010) as well as other literature such as Borko (2004) and Desimone (2009) while examining and further following up on references in this research. Specifically for each of the two key areas of PD research this dissertation centered on, secondary PD's effect on student achievement and long-term effects of PD on teachers, a more systematic review of the literature was conducted and the procedure for this is described in each respective section.

According to researchers, PD should have the following characteristics for

teachers in order to be effective: be focused on content, cultivate active learning, foster coherence, promote collaboration in learning, and be provided as a long-term experience for teachers (Desimone, 2009; Garet et al., 2001). These elements are recognized by many researchers, and Desimone (2009) recommends using these in the study of PD in order to test "both a theory of teacher change (e.g., that PD alters teacher knowledge, beliefs, or practice) and a theory of instruction (e.g., that changed practice influences student achievement)" (p. 185). Loucks-Horsley et al. (2010) adds another important part of effective PD and that is to encourage leadership opportunities. These elements of effective PD will be discussed and be utilized as a theoretical framework for this dissertation (Figure 1.).

These elements, generated by research on elementary schools primarily (Garet et al., 2001), may differ in high schools. For example, collaboration is important for teachers but different in high school as these teachers are more likely to work in isolation. Content knowledge is different for high school teachers because they generally must have specialized in their specific content and therefore content focused PD takes on a new meaning, especially for teachers who believe they are content experts. Additionally, active learning can be difficult to promote sometimes because most content specialists as found teaching high school learned their subjects very differently, in more of a lecture atmosphere. This will be discussed in greater detail below.

Figure 1: Theoretical framework.



This paper will now describe the elements of effective PD and how these provide a framework for studying PD.

Content focus.

One effective characteristic of PD is for it to be centered on the content that is to be taught in the classroom (Borko, 2004; Desimone, 2009; Garet et al., 2001; Higgins & Parsons, 2009; Kazemi & Hubbard, 2008; Loucks-Horsley et al., 2010). Rather than broad topics like collaborative learning of students or teaching with constructivism (Fishman & Davis, 2006), it is important for teachers to directly relate what they are learning into content focused tasks (Fishman & Davis, 2006; Garet et al., 2001; Loucks-Horsley et al., 2010; Wilson & Berne, 1999). Borko explains,

> …teachers must have rich and flexible knowledge of the subjects they teach. They must understand the central facts and concepts of the discipline, how these ideas are connected, and processes used to establish new knowledge and determine the validity of the claims. Professional development programs that include an explicit focus on subject matter can help teachers develop these powerful understandings. (Borko, 2004, p. 5)

In fact, in a broad investigation on PD, Garet et al. (2001) state that content focus is central to have high-quality PD. In 2010, Wei and colleagues reported on PD studies from the years 2004 to 2007 and found that the eight programs that revealed impacts on either teacher practice and/or the outcomes of students that were significant had "a strong

focus on content and content-pedagogy in math or science" (p. 6). When PD is founded in the content it effects more change in teacher practice and learning.

Promoting active learning.

The content focus is not enough, however, as teachers must also increase their own knowledge while in the PD (Wilson & Berne, 1999). Disseminating or delivering to teachers in a PD such as sharing a new curriculum or activity is not enough. Teachers must be activated and engaged in learning in similar ways that their students will be asked to approach learning (Loucks-Horsley et al., 2010). Teachers can do this in various ways such as active engagement in discussion regarding learning content or ways in which students learn, or perhaps involving planning or teacher practice. Additionally, teachers can be provided opportunities "to observe expert teachers and to be observed teaching; to plan how new curriculum materials and new teaching methods will be used in the classroom; to review student work…and to lead discussions and engage in written work" (Garet et al., 2001, p. 925). Essentially, PD should provide

> …a well-defined image of effective classroom learning and teaching. This image includes, for example, a commitment to all children learning mathematics and science, an emphasis on inquiry-based learning, investigations, problem solving, and applications of knowledge, an approach that emphasizes in-depth understanding of core concepts and challenges students to construct new

understandings and clear means to measure meaningful achievement." (Loucks-Horsley et al., 2010, p. 71).

Giving teachers opportunities for active learning in PD further develops the teachers' content and pedagogical knowledge.

Learning collaboratively.

Providing teachers with opportunities for active learning can be done in PD through collaboration and can be concentrated around learning the content and/or the way students learn the subject matter, that is, grounded in the PCK necessary for effective teaching. Learning collaboratively in a group is an effective part of PD because it fosters professional discourse about the way students learn certain concepts as well as helping improve teacher understanding (Borko, 2004; Garet et al., 2001; Loucks-Horsley et al., 2010; Ostermeier et al., 2010). When PD is done collaboratively it contributes to a professional culture that is shared, developing common ground regarding goals of instruction and methods of teaching through forums of debate and teacher growth. Collective learning allows PD to have a significant impact on teacher practice and/or student achievement (Wei et al., 2010, pp. 6-7)

Coherence.

Also it is important that PD be coherent so teachers can make connections to what happens in their classrooms and build on their own knowledge. Specifically, teachers

should see connections between the program and standards or assessments, building on previous experiences, and encourage professional communication with others who aim to reform instruction similarly (Garet et al., 2001). Teachers should see that what they are experiencing in the PD relates to what happens in their classrooms and have encouragement from colleagues to continue in the process of learning and implementing reform. Coherence occurs when PD experiences are linked to "parts of the education system" as a whole, such as the integration of "district or school initiatives, district or state curriculum frameworks, and assessments" (Loucks-Horsley et al., 2010, p. 71). There should be an explicit link among what happens in the teacher's school with regards to curriculum and organization in order to significantly impact teachers' practice or the achievement of students (Wei et al., 2010, pp. 6-7). The element of coherence is combined with the content element for this study's framework as the standards provide coherence for teachers. Other researchers have grouped two elements while analyzing PD, as well (Greenleaf et al., 2011, p. 667).

Research summarizes, "professional development that focuses on academic subject matter (content), gives teachers opportunities for 'hands-on' work (active learning), and is integrated into the daily life of the school (coherence), is more likely to produce enhanced knowledge and skills" (Garet et al., 2001, p. 935).

Long-term experience.

All of this learning takes time, however, and it has been found that effective PD needs to be conducted over longer periods of time (Garet et al., 2001; Ostermeier et al., 2010; Yoon et al., 2007). Some PDs are just a workshop that last only a day or two, but "a long term approach of professional development with a significant focus on classroom teaching instead of a one-shot attempt" is more effective in impacting the practice of teachers (Ostermeier et al., 2010, p. 310). For example, sustained PD that averaged 49 hours bettered student achievement by 21 percentile points, according to Yoon et al. (2007). Opportunities of PD should be ongoing so teachers have time to practice, plan, and work with peers (Schoenfeld, 2002). Unfortunately, there seems to be a decline in opportunities in long-term PD in the United States according to Wei and colleagues (2010, p. v), who report that in 2008 teachers had fewer opportunities for PD experiences lasting more than eight hours than four years previously.

Promoting leadership.

Facilitating opportunities for teachers to be leaders is another important feature of effective PD. This is done through the enhancement of professional expertise of teachers through the PD and then allowing the teachers to serve in leadership positions (Loucks-Horsley et al., 2010). Additionally, some research indicates that leadership fostered in PD can be more than just a role or assigned function in the school with a designated name or position. Instead, leadership "is a stance, a mind-set, a way of being, acting, and thinking

as a learner within a community of learners, and as a professional teacher" (Darling-Hammond et al., 1995, p. 95). Roles of leadership for teachers can take place either at their own schools supporting change and reform or perhaps presenting at a conference on teaching. Additionally, an alternate way of defining leadership in teachers can be a as a stance where teachers learn and develop, obtaining confidence as a professional in the field of education (Darling-Hammond et al., 1995).

Effective PD as a framework.

PD, therefore, is the most effective when teachers collectively work together on content-related tasks that promote active learning in a long-term setting and are encouraged to serve through leadership. The content-related tasks, when built on standards, help provide the coherence needed for teachers. As Figure 1 presents, an effective PD is long-term and utilizes collaboration, active learning, and tasks built on content that are aligned with standards in order to provide coherence for teachers while encouraging teacher leadership. The confidence gained through the fostering of leadership also can promote change in their respective schools and other teachers. The PD program in this study provided opportunities such as these for high school mathematics teachers. When these elements are present, teacher knowledge and practices are more likely to be affected which in turn, should affect student achievement. According to the National Staff Development Council as cited by Wei and colleagues (2010) , PD is "a comprehensive, sustained, and intensive approach to improving

teachers' and principals' effectiveness in raising student achievement" (2010, p. 4). The goal of effective PD then is to better student outcomes. Some studies have revealed this link for mathematics teachers, although most of this research has been done for the lower grades.

PD RESEARCH

Research on PD has mostly concentrated on studying effects on teacher knowledge and student achievement in elementary grades (Yoon et al., 2007), with some recent work in middle school (Garet et al., 2011; Garet et al., 2010; McMeeking, Orsi, & Cobb, 2012). To date, there seems to be little to no research that has been done for both changes in teacher knowledge and student achievement regarding PD given to high school teachers. In fact while searching for research specifically at the high school level only two studies were found, and the procedure used to find these two along with the discussion of them will be discussed later in the chapter. Most research in high school PD seemingly has focused on teacher knowledge and practice changes but not linking to changes in student achievement.

While PD research conducted in elementary or middle school can be informative, it is not uniformly applicable to high school. There is a difference in those teachers who work in high schools from their counterparts in the elementary level. High school teachers are generally content specialized, with either a degree in the subject they teach or perhaps technical or work experience in the field taught, conceivably believing they

are experts without a need of PD. They are more apt to work in isolation, away from colleagues than their elementary counterparts, avoiding collaboration, as well. Differences such as these can affect the way PD is received by high school teachers, and how it is put into practice. The students they teach are at the end of compulsory education and have fixed notions of schooling and probably many misconceptions as well, after numerous years in schools. This would affect the way students accept new reform teaching techniques, such as active learning opportunities learned by teachers in PD, therefore student achievement gains could possibly show little to no difference when in fact teacher knowledge and practice has changed. For that reason, research regarding teacher knowledge and practice as well as effects on student achievement is vital for PD research in order to better these programs for teachers of high school students.

This paper will now discuss well-known research results in the elementary level for PD and the effects on student achievement and teacher change. Following will be prominent research on PD for middle school teachers and the two works found at the high school level regarding PD's effects on student achievement. Some work on changes in teacher knowledge and practice for high school teachers will be discussed next. This discussion will provide a brief look at the current status of research on PD. After the review on high school PD and student achievement, implications for the research in this dissertation will be discussed.

PD AND STUDENT ACHIEVEMENT

Essentially, some studies work to link teacher change from PD to improvements in student learning and achievement. This is a very important part of research because the ultimate goal in education is to better meet the needs of all students. Yoon et al. (2007) explain, "Professional development for teachers is a key mechanism for improving classroom instruction and student achievement." (p. 1) However, even though it is logical to think that what teachers learn in PD would translate into alterations in practice that would then create changes in student achievement, these links are often hard to describe and even find (Wallace, 2009; Yoon et al., 2007).

There has been quite a bit of research in the area of PD for elementary teachers, which has included studies that work to link the teachers' PD to changes in teachers practice and beliefs that in turn affect student achievement. However, Yoon et al. (2007) reports that in examining over 1300 studies that looked for effects on student achievement from teacher PD only nine met the evidence standards for What Works Clearing House with all of these being at the elementary level. These nine studies were compared and analyzed and had the following general findings: PD for teachers "had a moderate effect on student achievement" and "the effect size was fairly consistent across the three content areas reviewed" (p. 2) with an average effect size in mathematics of 0.57 (p. 8); "studies that had more than 14 hours of PD showed a positive and significant effect on student achievement" (p. 3); and that the "average control group students would

have increased their achievement by 21 percentile points if their teacher had received substantial professional development" (p. iii). It is therefore feasible to expect PD that is long-term to improve student achievement.

CGI PD program.

One research program, centered at the elementary-level, has worked to expose links among elements in PD, teacher knowledge and practice, and student achievement (Desimone, 2009). This major research project that encompasses multiple studies was developed through the Cognitively Guided Instruction (CGI) framework (i.e. Carpenter, Fennema, Franke, Levi, & Empson, 2000; Carpenter, Fennema, Peterson, Chiang, & Loef, 1989; Fennema et al., 1996). The framework of CGI is provided in PD for teachers by engaging teachers in learning how students' mathematical thinking develops through building on the knowledge of the teachers. The research on CGI "found that teachers had a great deal of intuitive knowledge about children's mathematical thinking; however because that knowledge was fragmented, it generally did not play an important role in most teachers' decision-making" (Carpenter et al., 2000, p. 3).

Through participation in PD on CGI, teachers' beliefs and practices seemed to go through various levels. In particular, researchers of CGI describe these as beginning at Level 1 where "teachers believe that children need to be explicitly taught how to do mathematics…using standard procedures" with "little or no discussion of alternative

solutions" (Carpenter et al., 2000, p. 4). At Level 2 teachers start questioning children's need of explicit instruction and "provide opportunities for children to solve problems using their own strategies and show the children specific methods" (Carpenter et al., 2000, p. 4). These researchers recognize the next level, Level 3, as a turning point where "teachers believe that children can solve problems without having a strategy provided for them" and the understanding of student thinking heavily influences these teachers' classrooms (Carpenter et al., 2000, pp. 4-5). Teachers in Level 4a and 4b actually plan instruction with knowledge of children's thinking and use this knowledge to more deeply understand the thinking of children in general where they "continually reflect back on, modify, adapt, and expand their models in light of what they hear from students" (Carpenter et al., 2000, p. 5). Almost all teachers in a longitudinal study on CGI were found to be at Level 3 or higher.

This increase in teacher knowledge and use of the CGI framework did result in greater student achievement, specifically in problem solving; even though CGI does not emphasize skill development, there was not a difference in CGI classrooms and control classrooms in student command of skills. Further studies in teachers' use of CGI show hints of cumulative results for students where longer exposure over multiple years in CGI classrooms showed greater gains in "the second and third years of the study" (Carpenter et al., 2000, p. 6). The PD program CGI therefore modified knowledge of elementary mathematics teachers and this change was reflected in better student achievement. The

program was long-term and coherent to teachers practice with the main focus being on student thinking about mathematics, with collaboration and leadership not an explicit focus of the PD. The CGI PD presents a concrete instance where PD following most of the elements of the theoretical framework adopted in this dissertation proved effective in changing teachers' practice and beliefs as well as resulting in improved student performance.

Middle school PD and student achievement.

Other research on PD also shows links from the elements of the program to teacher change and student achievement. Although not much research has concentrated on upper grades, one study (McMeeking et al., 2012) utilized middle school data on students whose teachers had attended a long-term PD aimed at enhancing content knowledge and PCK. The PD was designed to:

> (a) increase teachers' efficacy and ability as mathematical thinkers with a focus on problem solving as well as problem posing; (b) build teachers' abilities to analyze the mathematical thinking of their students, including misconceptions as well as gaps in conceptual understanding; (c) revisit mathematical concepts embedded in the middle school and high school curricula so that teachers' knowledge would extend past the instructional level; and (d) develop instructional techniques for inquiry-based learning through the use of mathematics notebooks.

(p. 165)

The courses of this study were similar to the PD in this dissertation in that they were to enhance content knowledge that was coherent to the teachers as it was based on current curricula, and promoted active learning with collaboration and leadership not being a focus of the program. This middle school PD was also similar in that it was taught in two to three week sessions in the summer by university faculty with follow up sessions during one semester of the academic year. However this program was different because the teachers only had to be in the program for one year with new teachers each year participating and the PD in this dissertation had teachers participate for approximately three years.

McMeeking et al. (2012) measured the indirect effects of the PD on student achievement utilizing a cohort design where the control was found in historical data from the same school and teacher. According to the study, students with teachers with no PD compared to those with two or more courses have an increase of "odds of achieving proficiency ranging from 37% to 178%" (McMeeking et al., 2012, p. 174) The major findings concluded, "teaching mathematics teachers deeper content and how to use an inquiry-based approach to deliver that content does indeed translate into greater student proficiency in mathematics" and the more the PD teachers participate in, the better effects for students (McMeeking et al., 2012, p. 175).

Another study from 2010 (Garet et al.), reporting on the first year of implementation of a middle school mathematics PD program, did not show significant student gains compared to teachers not in the program. However, this study in which the participants attended about 67 hours of PD regarding rational number topics, did show a significant impact in teacher practice. Teachers were more apt to elicit student thinking, such as "asking students whether they agree or disagree with a particular student's response" or having students "offering additional justifications or strategies". (Garet et al., 2010, p. xviii). Also, the second year of this study (Garet et al., 2011) showed no significant gains in student achievement or in teacher knowledge when compared to non-treatment teachers. This PD was coherent as it was "designed to be relevant to the curricula that teachers were using in their classrooms" (Garet et al., 2010, p. xx). This program also provided teachers opportunities to work in groups on activities for further development of mathematics concepts; thus it was collaborative, centered on content, provided active learning for teachers and was long-term due to the number of average hours. The work by Garet and colleagues (2011; 2010) displays an example of a PD for middle school that seemed to have the characteristics founded in research of effective PD, as the PD in this dissertation except for the emphasis on the development of leadership in teachers yet the PD investigated by Garet et al. did not demonstrate student achievement gains.

There were several reasons the authors discussed as to why there was not a significant student achievement increase. Possible reasons were the way teacher change was measured for the study "may not be related to student performance in mathematics" or perhaps the measures were inaccurate because they measured the quantity of practices that were exhibited not the quality (Garet et al., 2010, p. 66). This program was for only one grade-level, that is 7th grade and was for a shorter period of time than the PD in this dissertation, only three days in the summer and then five separate one-day sessions during the year. Perhaps, after only one or two years, this program had not enough time to exhibit teacher and student change, or it is possible that measuring the change in teachers and students is harder to accomplish in upper grades.

Teacher PD and student achievement in high school.

In order to locate possible studies that investigated what teachers learned and put into practice from PD while investigating student achievement at the high school level, a search was completed using the databases of Education Source, ERIC and PsycINFO for the years 1994 to present. The specific search looked for the following terms: "teachers", "PD", "faculty development", "teacher development", "in service training", "teachers training of", and "academic achievement", while putting restraints on the search by using "NOT" for the following terms: "primary", "middle school", "junior high", and "college". After reviewing the abstracts of the 1073 articles and/or dissertations that were found in this search that met the criteria, 20 articles and/or dissertations were further

reviewed and from these only one article and one dissertation actually reported on PD's effect on teachers and student achievement at the high school level. One investigated a PD in literacy specifically for Biology and the other a PD on application and theory-based formative assessment. These two components will be discussed next with implications to the work in this dissertation to follow.

PD in literacy.

One high school PD program, discussed by Greenleaf and colleagues (2011), utilized a framework of instruction called Reading Apprenticeship to develop literacy practices in teachers specifically for the subject of Biology in schools with high minority and low socioeconomic student populations. This framework focuses on metacognitive strategies in reading science texts where teachers model tools of comprehension for students. In this study, "changes in teacher knowledge and instructional practices and student achievement in science and reading" (Greenleaf et al., 2011, p. 652) were investigated. This work utilized Desimone's (2009) framework of content focus and active learning, duration, collective participation, and coherence, similarly to this dissertation.

The study had 105 teacher participants from 83 different schools with those in the treatment group totaling 56 and the control group 49, with a random selection for each group. The duration of the PD was 10 days that took place over a year beginning in one summer and finishing in the following summer. Those in the control group were offered

the PD in the next summer after that so the teachers in this group could be used for the first two years as a form of treatment-as-usual. Teachers were surveyed and interviewed, classroom sample lessons were collected and assessed with a rubric. Students were surveyed as well as assessed on the state standardized tests in Biology and English Language Arts and Reading comprehension. As Greenleaf et al. (2011) note, the data

> …indicate that the intervention teachers were more knowledgeable about and more able to integrate the teaching of science reading with science content, to create classrooms characterized by collaborative inquiry and meaning making with science texts, to engage student in the work of text inquiry, and to offer their students tools in the form of comprehension routines and strategies to support their work with science texts (p. 698).

Student sources of data were found to show some evidence on increased student achievement on the standardized assessment with "effect sizes of 0.23, 0.24 and 0.28 on English language arts, reading comprehension, and biology". (Greenleaf et al., 2011, p. 700). These effect sizes, the researchers estimated, revealed that teachers' from the PD had students whose test scores indicate them being "about 1 year ahead of their counterparts in control classes at the end of the study" (Greenleaf et al., 2011, p. 701)

PD in assessment.

A dissertation study by Cole (2010) investigated PD for high school teachers focused on formative assessment. This study set out to discover if any relationships exist

between participating in the PD and student achievement, as well as teachers' perceived benefits of strategies learned. The study focused on teachers and students of grades 9-12 separated into three populations, namely Application-Based High School, Theory-Based High School, and Control High School. The PD on formative assessment was based on application for Application-Based High School and based on the theory for the Theory-Based High School, while teachers in the Control-High School did not receive the PD. Analysis of Variance was used with the three different schools and showed "that participation in Assessment for Learning PD is associated with improvements in students' performance on the Georgia End of Course Assessment" (Cole, 2010, p. 67). This study also found a significant relationship in teacher perception between teachers who received theory-based PD and those in the control group (Cole, 2010, p. 71). This study did not describe changes in teacher knowledge and practice.

Implications.

The relatively few works found in researching PD programs for high school teachers and their student's achievement indicate a need for research in this area. The Greenleaf et al. (2011) work utilized the framework of effective PD similarly to this dissertation. It also contained most of the elements of effectiveness as outlined by research. The work by Greenleaf and colleagues demonstrated a PD that did show student achievement on a standardized test increases in specific components that related to the PD, but did not report on an overall student achievement increase as in this dissertation.

The research by Cole (2010) describes a PD on assessment that was not content specific as multiple contents were used for student achievement results, and it is not apparent that the content was addressed in the forms of assessment. The program was not long-term (Cole, 2010, p. 51), and it is not evident that it had any of the elements of effective PD as identified by research, namely being long-term, content focused, coherent, and promoting active learning, collaboration as well as leadership. The student assessment was gauged using only three schools with one of them being a control, whereas this dissertation uses two PD schools and four control ones. The Cole work also did not outline teacher change in practice or knowledge from the PD as this dissertation has done.

Summary of PD and student achievement.

PD's effect on student achievement as mediated through teachers' practice, beliefs, and knowledge, has been studied with some positive results. Work with elementary teachers displays the long-term nature of PD to be important in affecting student achievement, as well as coherence (i.e. Carpenter et al., 2000; Yoon et al., 2007). The studies regarding middle school PD show mixed results in the impact on student achievement with no significant difference exhibited in the works by Garet et al. (2011; 2010) and favorable odds of bettering student achievement in the McMeeking et al. (2012) study. Systematic review of the research on PD for high school teachers and effects of student achievement yields only two works (Cole, 2010; Greenleaf et al., 2011) and of these only one had the major elements of effectiveness (Greenleaf et al., 2011).

This research in high school PD showed student achievement improvement but one work (Cole, 2010) did not describe what teacher change led to this improvement. More research is needed in order to provide a detailed account of teacher change while looking for impacts in student achievement for high school PD.

PD FOR HIGH SCHOOL TEACHERS

Research in PD for secondary teachers of mathematics has covered various topics such as school-based study groups, issues with designing and implementing PD for teachers of urban schools, PD that is about specific topics such as the use of technology, and changes in teacher knowledge from workshops, all without the design of looking for greater student achievement.

In order to build opportunities for high school teachers, whose propensity is to work in isolation, to begin to collaborate in improving the teaching of mathematics, a particular form of PD for the secondary level of teaching is the use of study groups. One specific research project (Arbaugh, 2003) centered on creating a school-based study group that had a goal to develop more inquiry-based geometry curriculum. This study focused particularly on teachers' experience in the study group and how they valued it. The main finding of the study concluded that "having the opportunity to collaborate with their peers on a regular basis and in a meaningful manner was one of the most useful aspects of study group participation" (Arbaugh, 2003, p. 158). Since collaboration is one

of the components of the theoretical framework adopted by this dissertation, it is more likely that the PD's effect through teacher change could result in student gains in achievement. The PD studied in this dissertation provided opportunities for collaboration, as this was one of the major focuses of the program.

Other work in PD for mathematics teachers of secondary schools focused on the complicated nature of teaching in urban settings. One such study (Brown & Benken, 2009) describes a purpose of developing a content-related PD for a group of three teachers who were in need of certification and worked in a high school in need of improvement academically. However, as the study evolved it became apparent to the researchers that there were needs of these teachers regarding context, including math anxiety and professional identity that needed to be addressed in order for the content goals to be achieved in the PD. Essentially the study concluded that both the context factors and long-term content focus had to be addressed in the PD (Brown & Benken, 2009). The PD program studied in this dissertation met the participants' needs of context and confidence through the concentration on standards or Texas Essential Knowledge and Skills (TEKS) through collaboration with other teachers who had similar types of students in their classrooms. Context relates to the theoretical framework piece, coherence and this study identified its importance. However, with only three teachers the collaboration recognized in the theoretical framework of this dissertation would be hard to facilitate, as it is limited. Leadership development or active learning is not explicitly

mentioned as being a part of this PD, either. The only framework components seemingly found in this PD would be content and context.

Some areas of research deal with PD that is related to a specific topic such as the use of technology in teaching mathematics. One such study (Bennison & Goos, 2010) concentrated on teachers' access, beliefs, and needs in technology-related PD. This research found that teachers with specialization in mathematics were more likely to attend PD on technology, that rural areas had less access to technology-related PD than urban ones, and that PD in technology promoted confidence and beliefs that were positive in nature regarding the use of technology for students in mathematics. In particular, the researchers found that there was specific need for technology related-PD specifically for mathematics because most teachers had experience with technology in less content specific ways. (Bennison & Goos, 2010). There are multiple technologies available for mathematics education today, such as graphing calculators and geometric software. However, these require specialized pedagogical knowledge to facilitate, as well as the know how in working the technology. Teachers need ongoing support on how to integrate, facilitate, and operate various new technology programs in their classrooms. The PD studied in this dissertation accomplishes this task.

Another very recent investigation centered on studying the learning of secondary teachers from a PD program called Enhancing Secondary Mathematics Teacher

Preparation (ESP) designed "to increased teachers' selection and implementation of instructional tasks that require students to think, reason, and make sense of mathematical ideas" (Boston, 2013, p. 14). This work utilized levels of cognitive demand and a framework of task analysis as described by Stein and colleagues (2000). The task analysis guide consists of high-level tasks, that is "doing mathematics tasks" and "procedures with connections tasks", as well as low-level tasks like " procedures without connections tasks" and "memorization tasks" (Boston, 2013, p. 12). A pre/post task card sort, utilizing the cognitive demand developed by Stein et al., was used to assess the teachers' knowledge from the PD. Summarizing the results of the study, Boston (2013) concluded teachers who attended the PD "significantly increased their knowledge of the cognitive demands of mathematical tasks and had significantly higher knowledge than teachers in the contrast group" (p. 26).

The Boston (2013) study presented the importance of teachers understanding teaching lessons with different cognitive levels. The teachers studied in this dissertation worked through various content related tasks that encouraged differing hierarchical levels of questioning, beginning where the teachers were comfortable and working up, utilizing methods of scaffolding as well. Teachers also worked through assessment items from the TAKS test by rewriting them at a higher cognitive level so they could better prepare their students for the upcoming change in standardized assessment, that is the End of Course exam (EOC).

RESEARCHING LONG-TERM EFFECTS OF PD

Since there are recommendations in abundance for PD to be more than just a one-stop workshop or short-term interventions, it makes sense to study and evaluate PD's impact on teacher practice with more than just summative assessments or a look at teachers' growth at the very end of the program. Instead, a look into the persistence or durability of effects can reveal long-lasting teacher change and learning from PD and therefore verify the worthwhileness of the program. Also, Kazemi and Hubbard (2008) argue that the implementation of what is learned in PD evolves as teachers enact these practices and ways of knowing in classrooms. Surely, this evolution continues even after the PD as teachers gain confidence and adapt practices. As a result, it is important to examine the long-term effects of PD so that these can better frame the design of PD programs.

Investigations of the persistence of teacher change from PD are reported to be a need by researchers (Antoniou & Kyriakides, 2013; C. Johnson, Fargo, & Kahle, 2010; Kazemi & Hubbard, 2008). In order to find work that has been done regarding long-term effects of PD in teachers, the databases Education Source, ERIC and PsycINFO for the years 1994 to present were searched for key words including "long term" or "longitudinal" and 571 articles/dissertations were found. The abstracts of these were reviewed and 15 were found to be relevant works. These articles were analyzed.

Support from others.

The few studies identified that investigated the long-term effect of PD had some commonalities. Several reported that it was very important for teachers to interact and have support from others implementing elements learned from the PD (Antoniou & Kyriakides, 2013; Dresner & Worley, 2006; C. Johnson et al., 2010; Knapp & Peterson, 1995). For example, while researching the impact of PD given to teachers on ecology it was found that some of the important outcomes carried over from the project were networks of teachers to help put into practice what was learned and collaborations fostered with scientists in the field of ecology (Dresner & Worley, 2006). Having likeminded people to work with rather than trying to implement new ideas alone was very beneficial to teachers. Teachers from a long-term PD for middle school science that promoted creating professional learning communities, exhibited continuous "growth in teaching effectiveness" three years after the program with this growth being statistically significant (C. Johnson et al., 2010, p. 152). Also Antoniou and Kyriakides (2013) concluded after a PD program called Dynamic Integrated Approach that growth in teachers required systematic continuation of participation in effective PD, and that stimulation and environments that are supportive are necessary. Knapp and Peterson (1995) reported after investigating the longevity of the CGI program that "change is gradual" and required support consisting of "ongoing conversation and interaction with other teachers" (p. 60).

Differing levels of enactment.

Several studies investigating the long-term effects of PD seemed to identify different levels of enactment of program objectives and these were labeled accordingly (Knapp & Peterson, 1995; Miller, 2012; Stronkhorst & van den Akker, 2006). One such dissertation study (Miller, 2012) investigated a PD on literacy strategies a year after the three-year program and found that teachers could be grouped into one of four types: Drifters, Villagers, Developers, and Navigators. These "systematically illustrate the different levels of adoption and implementation practices of participant teachers that emerged from the analysis of teachers' self-reported interviews", classroom observations, questionnaires, and field notes (Miller, 2012, p. 106). Drifters were categorized as being "resistant to new ideas and emphasized personal ownership of classroom instruction" (Miller, 2012, p. 103). Villagers were also resistant to change in their practice, but also held on to "traditional teacher-centered approaches to instruction" because of belief that the status quo was better for their students (Miller, 2012, pp. 103-104). Developers on the contrary were seeking learning experiences that are research-based and interested in promoting change for the advancement of student understanding. However, Developers did not show the intensity of implementation regarding change in instruction as Navigators. This group of teachers were characterized as being "driven by how students' learn" while rarely being held back by school or district rules (Miller, 2012, p. 105).

Navigators were found to be "thinking outside of the box and exploring how adolescents learn best" (Miller, 2012, p. 105).

Knapp and Peterson (1995) also found teachers to have differing levels of implementation of PD practices. There were three types of teachers identified, those who gradually increased their use of CGI, those who used it occasionally, and those who used CGI when it was introduced but did not use CGI as much afterwards, labeled groups one, two and three respectively. The teachers who increased the use of what was learned in the PD on CGI found that "the continuing opportunity to interact with other teachers who were trying to use CGI was a vital factor" for "development and change" (p. 47). Those in the third group who did not continue using CGI reported a lack of collegial support as a reason (p. 56). Teachers who used CGI occasionally from group two seemed to be settled in this use with little to no growth in actually utilizing children's thinking as CGI promoted and seemingly "proceduralized the intervention" (p. 61). The group three teachers who used CGI at the beginning but then hardly used it in later years seemed to have many obstacles for implementing CGI and seemed to have a "gap between what these teachers said they thought was important in mathematics teaching and what they reported actually doing in their classroom practice" (p. 55).

Personal initiative.

Research investigating PD's long-term effect on teachers seemingly indicates that personal initiative on the part of the teacher was important for long lasting results

(Erickson, Minnes Brandes, Mitchell, & Mitchell, 2005; Frederick, 2013; Miller, 2012). While investigating a PD ten years after the intervention Frederick (2013) pointed out that what was learned in the program on technology opened up other career paths in education for participants (p. 72). The Johnson et al. (2010) study also pointed out growth from PD coming from the initiative of teachers: "Teachers continued to refine their practice and realize gains in teaching effectiveness through initiating other development activities such as study groups and attending state and national science association meetings" (p. 153). This research seems to imply that the PD influenced the teachers to better themselves through further study and advancement in their careers. Another work commented that continued involvement of teachers in PD show satisfaction and commitment (Erickson et al., 2005, p. 794). So teachers that seek out even more PD exhibit a longing for improvement in their practice and dedication to reform developing leadership not unlike that discussed previously and recommended by Darling-Hammond et al. (1995).

Applications to this work.

Research on the durability of PD seems to point to a necessity of community support for teachers to continue to sustain and continue in changing their practice. Since support from others is an important factor for long-term change this dissertation study centered on two schools where all the Algebra I and Algebra II teachers participated and the likelihood of support from other teachers is increased. Collaboration and support in

teacher practice was addressed through interviewing teachers and was analyzed. Also, teachers implement elements of PD in differing levels or ways over time. This study looked for commonalities among teacher enactment of the PD's principles to see if different levels can be found in teachers' practices. These levels, when they exist, are grouped and a name or label given to aid in the analysis similarly to other studies. Motivation by the teacher for improvement also influences the long-lasting results of PD. Therefore, this work also looks at ways teachers' motivation to further their own development aids in long-term change and report on this phenomenon through the construct of leadership.

SUMMARY AND CONCLUSIONS

Work in PD for secondary teachers concentrates mostly on teacher needs and change without the concentration of looking at how or in what ways this change can create better student achievement. According to Yoon et al. (2007), there were no studies that meet evidence standards of What Works Clearing House at the middle or high school level to investigate teachers' change in practice from PD experiences that result in changes in student achievement. Research in this area should aim to show "links among PD, teacher learning and practice, and student learning" and provide "empirical evidence" (Yoon et al., 2007, p. 3). This next chapter will describe the plan of this dissertation to meet these needs in research, as well as the necessity for investigation of long-term effects of PD on teachers as recommended by Kazemi and Hubbard (2008).

Chapter Three: *Methodology*

The purpose of this dissertation was to investigate the effects of PD for high school mathematics teachers both on student achievement and change in teacher knowledge and practice. Research recommends a pragmatic approach that allows methods to be mixed in order to best answer the research questions (R. B. Johnson & Onwuegbuzie, 2004, pp. 15-16) and this study's research questions necessitated this tactic. Research question one regarding change in student achievement relied on quantitative methodology with some description regarding possible outside factors that may have influenced student achievement provided by teacher participants. Research questions two and three primarily were answered via qualitative methodology with quantitative analysis supplementing.

Qualitative methodology in educational research helps provide "knowledge of the particular" and of the "complex and changing networks of social interaction" (Berliner, 2002, p. 19), whereas, the quantitative methodology can help test hypotheses about how and why phenomena occur (R. B. Johnson & Onwuegbuzie, 2004, p. 19) Utilizing both qualitative and quantitative research in a study "produces more complete knowledge necessary to inform theory and practice" (R. B. Johnson & Onwuegbuzie, 2004, p. 21).

Quantitative methodology

The research paradigm that established the context for the quantitative methodology is postpositivism, which has the goal to explain and predict phenomena as an objective reality but acknowledges that it is not perfectly captured (Ponterotto, 2005, p. 129). In other words, this dissertation modeled the quantitative methodology via critical realism, in the understanding that science can look for cause and effect but reality "can only be apprehended and measured imperfectly" (Ponterotto, 2005, p. 130). Therefore, discussion about possible errors and other explanations of the results are included in the analysis.

The quantitative methodology utilized in this dissertation consisted of a dependent T-test. The details, assumptions, and hypotheses are explained in the section for Research Question Two further in this chapter.

Qualitative methodology.

The constructivism paradigm guided the qualitative methodology. That is, "concepts and theories are constructed by researchers out of stories that are constructed by research participants" (Corbin & Strauss, 2008 p. 10) This is built epistemologically on pragmatism, the creation of knowledge through both action and interaction and the usefulness of inquiry in this process in order to accumulate knowledge (Corbin & Strauss, 2008 pp. 2-5).

The constructivist perspective contends, "that concepts and theories are *constructed* by researchers out of stories that are constructed by research participants who are trying to explain and make sense out of their experiences and/or lives, both to the researcher and themselves" (Corbin & Strauss, 2008 p. 10). Since the researcher constructs concepts, reflexivity while collecting and analyzing becomes critical. Part of reflexivity is a personal examination by the researcher for background and experiences that affect the way the data is perceived and processed (Corbin & Strauss, 2008, p. 31). This researcher previously worked as a high school math teacher for six years and participated in the PD program discussed here. By nature, this researcher is optimistic and felt the PD was a positive experience that propelled her to undertake additional education and helped her improve her teaching. This outlook could have skewed results. Therefore, throughout analysis memos were written and self-reflection took place in order to minimize possible bias. On the other hand, the researcher's background with teaching and the PD was beneficial because it provided intimate knowledge and understanding of the teacher data that would not have otherwise been possible. Shenton (2004) recommends the researcher establish "familiarity with the culture" (p. 65), and in this case this familiarity was born of undergoing the PD as participant. Qualitative research benefits from data immersion.

Although the constructivism paradigm proposes that multiple realities exist (Ponterotto, 2005, p. 129), this dissertation worked to build validity and reliability into

the study through the triangulation and the use of the well regarded grounded theory methodology (Corbin & Strauss, 2008 ; Ponterotto, 2005).

Validity and reliability.

In order to facilitate validity and reliability, or their qualitative counterparts credibility, transferability, dependability, and confirmability, several safeguards were be built into the study, as commonly recommended (Lincoln & Guba, 1985; Shenton, 2004). The main one is the adoption of a well established research method (Shenton, 2004, p. 64). In this study the research method is grounded theory, where concepts or themes are developed from data in order to build theory (Corbin & Strauss, 2008). This method is chosen for this study because researching PD research for high school teachers in tandem with investigating student achievement is not common (Yoon et al., 2007) and a better description of long-term effects of PD on teachers is needed in research (Kazemi & Hubbard, 2008). Grounded theory methodology was used in this dissertation in order to build theory for this underdeveloped field of PD research, that of PD's effect on high school teachers and the longevity of these effects.

Effective PD, according to research, provides a long-term opportunity where teachers work through content, are provided opportunities for active learning through collaboration, encouraged to engage in leadership roles, and where the opportunity is coherent with the teachers' environment (e.g., Borko, 2004; Garet et al., 2001; Loucks-Horsley et al., 2010). The theoretical framework incorporates key components of

effective PD and structures this analysis so links to existing research can be made for the study of high school PD, as recommended by Desimone (2009). In particular, the analysis focused on teachers' growth in the following areas: content, active learning pedagogy, collaboration and leadership. Other research in analyzing teacher data from participation in PD regarding high school mathematics also used research-based categories to further reduce and chunk data (Arbaugh, 2003, p. 146).

Additionally, researchers (Lincoln & Guba, 1985; Shenton, 2004) recommend triangulation and the use of overlapping methods to ensure credibility, dependability and confirmability. This is accomplished in this study through the use of multiple data sources including observations, teacher interviews, teachers' written reflections during the PD, and pre/post assessment information, with the teacher data coming from two different schools in two different school districts. Thick description of results helped enable transferability in the study (Shenton, 2004, pp. 69-70). Member checks also were conducted during the interview to bolster credibility (Shenton, 2004, p. 68).

Finally, the research methodology conducted in this dissertation was reviewed and approved by the Institutional Review Board (IRB) and the approval letter can be found in Appendix A.

Grounded theory methodology.

The qualitative method grounded theory (Corbin & Strauss, 2008) was used in analysis of the interviews and written reflections, that is, "theoretical constructs derived

from qualitative analysis of data" (p. 1) were generated. When looking at the teachers' responses, open coding was used to gather main ideas or concepts from the data (Corbin & Strauss, 2008 pp. 66, 160). Open coding is the process of " breaking data apart and delineating concepts to stand for blocks of raw data" (Corbin & Strauss, 2008 p. 198) and was utilized in order to gather commonalities of teacher perceived change from the PD. As recommended by Corbin and Strauss (2008), coding took place throughout data collection and memos were written to describe the analysis process and the concepts as they develop for each of the theoretically derived categories. Analytical tools utilized for this process were questioning of the data, making comparisons, personal experience, and looking for temporal words (Corbin & Strauss, 2008 p. 69). While open coding takes place, axial coding, that of "relating concepts/categories to each other" (Corbin & Strauss, 2008 p. 198) furthered the analysis to find relationships between concepts and a better understanding of the way PD impacts teachers' practice and knowledge including the longevity of those changes.

According to Bogdan and Biklen (2003), the interview in a qualitative study "is used to gather descriptive data in the subjects' own words so that the researcher can develop insights on how subjects interpret some piece of the world"(p. 95). Semi-structured interviews were conducted with the teachers to gather further information for each of the concentrated areas of analysis. Semi-structured interviews were chosen because they allowed for comparable data among teachers with a balance of some

structure (Bogdan & Biklen, 2003, p. 96). Comparing similar data from two time points (written reflections during the PD, and interviews two years after the PD) provided a look at how the teachers' change stands or is modified over time.

CONTEXT AND SETTING

The teachers in this study took part in a PD program provided by a South Texas university that was based on needs assessment survey completed by the specific South Texas school districts involved in the PD. This PD was provided for teachers from two low-performing, high-minority districts. The program met for 2-3 weeks each summer and once a month during the academic year from June 2009-December 2011(approximately three years). The design of the PD is to be a long-term enrichment of content and current research based practices for the teachers. There were two groups of teachers arranged by content taught, namely Algebra I and Algebra II. Teachers collectively engaged in actual content activities relating the mathematical relationships of the topics to teaching. Some example activities were specific to topics like conics or quadratics, and some were related to ways technology can be appropriately integrated into instruction; for example, use of calculators and interactive geometric software to facilitate activities for visualizing Algebra topics were included in the program. Sometimes the teachers engaged in careful examination of student state assessment questions of content and created questions through group discussion for the distractor (wrong) answer choices of the assessment. The PD also included attending mathematics

teacher conferences such as Conference on the Teaching of Mathematics 6-12, Conference for the Advancement of Mathematics Teaching (CAMT) and Mathematics for English Language Learners Conference (MELL). At the conferences, the teachers were encouraged to engage as leaders by preparing presentations individually or in groups, as well as attending sessions related to teaching mathematics. Once a year the teachers created and presented lessons to the other teachers in the PD either as a group or individually to cap off that academic year.

Participants.

The teachers in this study are a part of the group that participated in a three-year PD provided by a South Texas University, and are from two urban, high-poverty high schools (School 1 and School 2). The teachers were chosen because the two schools had all the Algebra I and Algebra II teachers participate in the PD program and this would allow a school student achievement data as reported by the Texas Education Agency (2012) (by school) to reflect on the impact of the PD. A total of 15 teachers, with six being from School 1 and nine being from School 2, were asked to participate in this study.

Of the fifteen teachers in this study, only one had a degree in mathematics, nine had degrees in general mathematics or mathematics education and the other five had degrees in other subjects. The number of hours of coursework in mathematics ranged from four to

thirty-six and the average number of mathematics hours was twenty-three. Seven out of the fifteen teachers were not certified to teach mathematics before entering the PD.

Aims of the PD.

The focus of the three-year PD was to enhance the confidence and competence of teachers who were uncertified, teaching out-of-field or not classified as highly qualified from two struggling, high minority, school districts in South Texas, in order that instruction of students might improve. Teachers collaboratively worked through activities that encouraged exploration and the use of technology in the program in order to increase their content knowledge and develop their teaching strategies centered on TEKS objectives, promoting coherence, as well as to encourage the teachers to become leaders. These combined characteristics provided PD for these teachers that should be effective according to research.

This program not only provided opportunities to increase teacher understanding of mathematics, it also promoted collaboration of teachers regarding student needs and misunderstandings. Additionally, the focus of this PD on standards-based practices promoted reform ways of teaching that have been found to enable more students to perform well and diminish the performance gap (Schoenfeld, 2002) . In summary, this PD sought to develop teachers' competence and confidence with State standards or TEKS in the realms of both knowledge and pedagogy, in order to support as instruction that is standards-based, constructive, technology based, explorative, collaborative, and

inclusive, while promoting the development of leadership through support and collaboration with peers. The pedagogical components promoted teachers' content knowledge, PCK, and various forms of active learning pedagogy.

PD objectives linked to theoretical framework.

Content knowledge was promoted through the emphasis of the TEKS or standards of the state, which made the PD coherent for the teachers. Active learning pedagogy in this PD provided teachers with instructional strategies that were explorative, inclusive, standards-based, and encouraged group activities. The use of technology as a tool in promoting student learning and understanding is consistent with content and active learning pedagogy and therefore compatible with effective PD elements. Collaboration in the PD was utilized to have teachers work together through content, technology, and activities, as well as a way to promote leadership in teachers. Support and encouragement of teachers' growth in leadership was promoted through teacher presentations at workshops as well.

INSTRUMENTS AND DATA SOURCES

In order to answer the research questions in this study data on both students and the teachers were utilized. The data sources (Table 1) used in this dissertation were student state assessment passing percentages, teacher interviews, teachers' written reflections, teachers' pre and post assessment, and teacher observations.

Table 1: Data sources, dates, and research questions.

Data source	Date of source	Research question
Student assessment (TAKS)	Each year in April (2008-2012)	One
Teacher interviews	Summer and Fall 2014	One, Two and Three
Teachers' written reflections	During the PD June 2009-Dec. 2011	Two
Teacher assessment "Algebraic Ideas"	Before and after PD 2009 & 2011	Two
Teacher observations	Fall 2014	Three

Student assessment.

For Research Question One this study investigated student achievement from a pre/post PD viewpoint with state assessment data. Specifically, data utilized in this dissertation were the percentages of students at a particular school who met standards set by the State for each of the grades 9^{th}, 10^{th} and 11^{th} on the Texas Assessment of Knowledge and Skills (TAKS). The data were analyzed for each of the schools (Schools 1-6) in this study for the years 2008-2012

The student-passing rate from the TAKS was utilized in this dissertation. The TAKS is a valid measure over the years because it is based on the objectives of the state, Texas Essential Knowledge and Skills (TEKS) and has been successfully tested for correlation with other college readiness exams such as the American College Test (ACT) and the SAT (Texas Education Agency, 2007-2008, Chapter 17, pp. 162, 165). The state

determines the number of questions that must be answered correctly in order to meet standards each year. Since there are multiple "influences besides teaching that can affect student scores over the course of a single year", researchers have used "gains over 3 years" as a more robust indicator of growth (Wallace, 2009, p. 581). Therefore, this dissertation study used the average passing rate of the two years before the PD and the three years of the program to assess possible student gains.

The TAKS grade-levels 9, 10 and 11 each assess algebra concepts, and the main emphasis in the PD researched in this dissertation was Algebra I and Algebra II content. The principal focus of the summer sessions of the PD was content, and throughout the academic year PCK was emphasized. Table 2 shows the main content covered for Algebra I and Algebra 2 in standard font and PCK developed through PD activities (many through the use of technology such as calculators and interactive geometric software) in *italics*. The academic year sessions provided some opportunities for both Algebra I and Algebra II teachers to have joint sessions or cover similar content/PCK.

Although the PD program had a principal emphasis on Algebra I and Algebra II content, many TAKS objectives were covered in the PD (more than just the five specific to algebra as exhibited in Table 2). Only Objective 8 had very little coverage, and this objective focused on content and extensions from 8th grade mathematics. Topics relating to functions, linear equations, other non-linear functions, and even geometry were included in the PD in either the summer sessions and/or those in the academic year. The

Table 2: TAKS objectives and PD's content.

Objectives	**Alg 1 PD**	**Alg 2 PD**	**Both Alg 1 and Alg 2**
Obj 1: Functional Relationships **9th: 5 questions** **10th: 5 questions** **11th: 5 questions**	*Functional relationships *Multiple representations of functions *Functional notation and algebraic generalizations *Modeling algebraic expressions through geometric models	*Foundations for functions	*-Building rules to represent functions* *-Abstracting from computation*
Obj 2: Properties and attributes of functions **9th: 5 questions** **10th: 5 questions** **11th: 5 questions**	*Functional relationships *Multiple representations of functions *Functional notation and algebraic generalizations	*-Absolute value functions* *-Exponential functions* *Foundations for functions *Focusing on parent functions and change in parameters	
Obj 3: Linear functions **9th: 5 questions** **10th: 5 questions** **11th: 5 questions**	*Basics of algebraic reasoning *Slope/rates of change implications *Transformations on linear equations *Interpreting zeros and intercepts	*-Comparing graphs, tables and equations* *Algebraic reasoning	*-Point-slope of a line* *-Slopes of parallel and perpendicular lines*

Table 2 (continued)

Obj 4: Linear equations and inequalities **9th: 5 questions** **10th: 5 questions** **11th: 5 questions**	*-Investigating slopes and intercepts* *-How slope is measured* *-Solving linear equations* *-Graphing linear inequalities* *-Solving inequalities by balancing* *Slope/rates of change implications *Transformations on linear equations *Interpreting zeros and intercepts	*-Matrix transformations*	*-Point-slope of a line* *-Slopes of parallel and perpendicular lines*
Obj 5: Quadratic and other nonlinear functions **9th: 4 questions** **10th: 5 questions** **11th: 5 questions**	*-Factoring trinomials* *Modeling algebraic expressions through geometric models	*-Parabolas in vertex form* *-Factoring and graphing quadratics* *Focus and analysis on rational, exponential, and logarithmic functions	*-Exploration of Quadratic graphs* *-Quadratic function theory*
Obj 6: Geometric relationships and spatial reasoning **9th: 4 questions** **10th: 5 questions** **11th: 7 questions**	*Relating algebra and geometry *Modeling algebraic expressions through geometric models	*In-depth analysis of relationship between geometry and algebra that describe the conics	*-Slopes of parallel and perpendicular lines* *-Rectangle with maximum area* *-Pythagorean Theorem* *-Coordinates*

Table 2 (continued)

Obj 7: 2D and 3D Representations **9th: 4 questions** **10th: 5 questions** **11th: 7 questions**	*Slope/rates of change implications	*In-depth analysis of relationship between geometry and algebra that describe the conics	-*Coordinates*
Obj 8: Measurement **9th: 6 questions** **10th: 7 questions** **11th: 7 questions**			-*Pythagorean Theorem*
Obj 9: Percents, proportions, probability, and statistics **9th: 5 questions** **10th: 5 questions** **11th: 5 questions**			
Obj 10: Mathematical processes and tools **9th: 9 questions** **10th: 9 questions** **11th: 9 questions**	*Basics of algebraic reasoning	*Algebraic reasoning	-*TI Nspire calculator* -*Coordinates*

* Summer content focused sessions

Bold: number of questions on grade-level TAKS test per objective

- *Academic year PCK focused sessions*

Objectives from (Texas Education Agency, 2002)

exact breakdown of the tested objectives on TAKS by grade level is included in Table 2 in **bold**.

Therefore, the TAKS was an appropriate tool for assessing the achievement of students whose teachers took part in the PD with an emphasis on algebra concepts. This assessment has been well tested with other recognized exams and is valid in measuring student achievement gains. Assuming that the curriculum is heavily influenced by the state standardized exam, there was a good match between PD content and the material teachers covered in class.

Teacher interviews.

The teachers who participated in this study were interviewed two years after the PD's completion. Eleven of the 15 teachers from the two schools were contacted; the others never responded to various email attempts and up-to-date information on how to contact these teachers was not available. These interviews ranged from about 15 min to an hour in length and all took place in person except for one phone interview for a teacher who had moved to another state. The interviews were audio recorded, transcribed and guided by a protocol (see Appendix B). Data from the interviews were utilized in answering Research Question One, Two and Three.

Teachers' written reflections.

During the professional development the teachers responded in writing to several prompts and the teachers' responses to these were used for this study. The teachers' responses to three different writing prompts were analyzed and are called written reflections in this dissertation. These helped answer Research Question Two.

Teacher assessment.

The teachers took both a pre and post assessment as a part of the PD. The assessment was the "Algebraic Ideas" test developed by the University of Louisville Center for Research in Math and Science Teacher Development, which is a part of the Diagnostic Teacher Assessment of Mathematics and Science (DTAMS). One purpose of the test according to the developers is:

> …to describe the breadth and depth of mathematics content knowledge so that researchers and evaluators can determine teacher knowledge growth over time, the effects of particular experiences (courses, professional development) on teachers' knowledge, or relationships among teacher content knowledge, teaching practice, and student performance…
>
> (University of Louisville, n.d., DTAMS section)

The assessment was created through "national recommendations, national and international test objectives, and research to determine appropriate mathematics content" (University of Louisville, n.d., DTAMS section). The DTAMS has been tested for

validity and reliability (Saderholm, Ronau, Brown, & Collins, 2010; University of Louisville, n.d.), with a Cronbach's alpha for the "Algebraic Ideas" portion computed to be 0.87 (University of Louisville, n.d., DTAMS section, para. "Establishing Reliability"). Previous research (Copur-Gencturk & Lubienski, 2013; Eli, Mohr-Schroeder, & Lee, 2013) has utilized the DTAMS to measure teachers' mathematical knowledge for teaching. This test contains both content- and pedagogy-based items and was scored by the developers of the test at the University of Louisville. The teachers' scores on the "Algebraic Ideas" test were used as a way to gauge teacher change in content knowledge and in pedagogical knowledge in order to address Research Question Two.

Teacher observations.

Of the eleven teachers interviewed, nine were observed, as one teacher no longer teaches and one (who taught in an alternative classroom) did not want to be observed. Teachers were observed two years after the PD's completion and field notes were taken during the observation. The observations were utilized as a triangulation tool with the teachers' self-reported changes in practice and knowledge.

A possible limitation in teacher observations was that these were arranged in advance through email with the researcher with a specific day agreed upon by the teacher. Although this could have allowed the possibility of a specially prepared lesson for the observation, this was unlikely according to the perspective of the researcher. The teachers gave many indications that the lesson observed was typical through seemingly

normal procedures and fluid presentation; in addition, some teachers apparently had forgotten about the scheduled observation.

RESEARCH QUESTION ONE: PD'S EFFECT ON STUDENT ACHIEVEMENT

The aim of the first research question of this study is to discover how student achievement changed after the teachers participated in the long-term PD program. To do this, two high school campuses were chosen because all the Algebra I and Algebra II teachers at these schools attended the program. Academic Excellence Indicator System (AEIS reports) for the beginning of the PD in the year 2010, presented that one high school's (School 1) student population is 39.7% Hispanic, 56.5% African American, and 3.5% non-Hispanic White, while being 93.2% economically disadvantaged and 6.5% limited English proficient. The other school (School 2) also had a high minority population that consisted of 94.9% Hispanic, 1.6% African American, and 3.2% non-Hispanic White, with 82.9% economically disadvantaged population and 5.4% of the population being limited English proficient. These figures remained nearly constant for the period of time examined. A comparison of student data before the teachers participated in the program and during the PD itself sheds light on possible effects of the PD.

Student data were retrieved from the Texas Education Agency (TEA) website for two years before the PD period and three years of the program. The program began in the summer of 2009 and ended in the middle of the 2011-2012 academic year. The Texas

Assessment of Knowledge and Skills (TAKS) test was given each Spring, so data for the years 2008-2012 of students in grades 9, 10 and 11 were analyzed for this study, with 2008 and 2009 as a measurement before the PD and 2010, 2011, 2012 during and afterwards. The State began to phase out the TAKS test in the year 2012, so for that year only 10th and 11th grade data were available. The student assessment data were given in the form of percentage of students who met the standard. The actual scores of the students were not available, so the percentage of students who passed the test as determined by the State was used as a measure of achievement. The percentages who met standard for the two years before the program were averaged for a pre-measurement and the data from two (9th grade) or three (10th and 11th grade) years during the program were averaged to form a post-measurement for each of the grade levels of each of the schools (School 1 and School 2) whose Algebra I and Algebra II teachers participated in the PD, utilizing a modified cohort design (McMeeking, Cobb, & Basile, 2010). The cohort design (McMeeking, Cobb, & Basile, 2010) is modified because the TAKS data analyzed consisted of entire grade-level percentages of students that met standards and was not available by teacher.

When comparing student achievement for the pre-PD and during-PD periods in order to determine whether the PD had an effect, the question arises of whether the same teachers were at each school for both periods. Continuity in the teachers means that any change might be due to the PD, whereas a change in the teacher population introduces a

confounding factor. At School 2, all of the nine teachers who participated in the PD were teaching there two years before the PD. However, in School 1 only one teacher confirmed teaching at that school the two years before the PD; two teachers did not reply to emails; and three of the six teachers were new to School 1 at the start of the PD. This turnover at School 1 is a limitation of this study.

Comparison schools.

In order to try to account for possible confounding factors, this study used four comparison schools in the same geographic area whose teachers did not participate in the PD. As the PD schools were high minority and high poverty schools, comparison schools were chosen that had similar demographics. . Since both minority status (African American and Hispanic) and qualifying for free or reduced lunch are recognized indicators of disadvantage for students (Pallas, Natriello, & McDill, 1989) and they have both been used independently as an indicator of disadvantage in research (e.g., Blank, 2011; Levine & Eubanks, 1990), they were combined in an index without weighting, by adding the percentages. The schools whose teachers took part in the PD in this study (School 1 and School 2) had an index of 189.4 and 179.4 respectively. The other four comparison schools had indexes between these two of 186.5, 186.2, 186.2 and 184.7. These four are named School 3, School 4, School 5 and School 6 to maintain anonymity.

Teacher interviews.

Teachers were asked to respond to questions in interviews that took place two years after the PD, regarding other possible reasons for an increase in student achievement. Teachers were asked to respond to: "Describe what interventions were provided for students for the years of the PD. Were there afterschool programs? Pull-outs? Change in curriculum from 2 years before PD through the PD? Other possible causes for increased student achievement in math?" Teachers' responses to these questions are described in order to identify other possible reasons that could have contributed to student achievement differences.

Interviews were guided by a protocol (see Appendix B), consisting of questions similar to those asked during the program in the written reflections along with other questions suggested by the theoretical framework. Interviews were audio recorded and transcribed. Teachers' responses were analyzed for temporal cues, and when the teacher specified information from the program years, it was reported for Research Question One and Two. When the teachers' responses indicated that they were about the present time, they were reported for Research Question Three.

RESEARCH QUESTION TWO: TEACHER CHANGE IN PRACTICE AND KNOWLEDGE DURING THE PD

To assess teacher change during the PD, the "Algebraic Ideas" assessment and teacher responses to written reflections from the PD period were utilized. These two were augmented with data from interviews, which occurred two years after the PD.

Analysis.

To answer Research Question Two, data from the years of the PD including the written reflections and teacher assessment were analyzed. Data from the interviews that referred to the PD period were also used. Grounded theory was used for the qualitative part of the analysis and a dependent T-test for the teacher assessment. The analysis was structured according to the theoretical framework and is described below.

Content.

Changes in teacher knowledge regarding both content and pedagogy were assessed through the "Algebraic Ideas" test, which the teachers took at the beginning and end of the PD. A dependent t-test was used to test for statistical significance and effect size. For this test the time period (pre- or post-test) is the independent variable and the dependent variable is their test scores. Since the two test scores are related as they belong to the same teacher, a dependent t-test was appropriate. The assumption of normality was tested via the Shapiro-Wilks test. The data was continuous and had no major outliers.

Additionally, teachers' reflections about content knowledge written during the PD program were used to describe shifts in teacher knowledge. The teachers' reflections were written in response to the following questions:

> How did the PD experience expand your depth of understanding of the concepts related to your area of teaching? How did this expanded depth of knowledge help you in your teaching? How has your deeper understanding of this content increased your awareness of the interconnection to other conceptual areas and topics?

Since these questions are biased in assuming an expansion of understanding occurred, some limitations occur in analysis of these particular reflections. The interview questions corrected this biased wording, asking instead: "Was your understanding of concepts related to your area of teaching enriched or expanded; and if so, in what ways?" The self-reported change in teachers' content knowledge as seen in the written reflections was chunked into main concepts through grounded theory methodology.

Active learning pedagogy.

In order to analyze pedagogical changes, artifacts from the years of the program, the teachers' responses to written reflections from the years of the program were again utilized. Teachers' written reflections in response to the following question generated relevant data: "How did your PD experience impact your thinking about teaching and learning? Discuss how these ideas helped you plan and explore new teaching methods as

a result." Teachers responses to this prompt were examined for indications of student-centered forms of learning and chunked into themes to provide a picture of the main areas of reported change.

Collaboration.

To investigate collaboration, written reflections responding to a specific prompt were utilized as well as questions in interviews with the teachers. The particular question in data from the program years was: "Describe how you communicate and collaborate with your fellow PD teachers between PD sessions. How do or could these collaborations enrich your practice?" The teacher's responses to this question were analyzed for commonalities and labeled as themes to create a description of teacher development from the program in this important area.

Relationships across elements of theoretical framework.

Although responses to specific questions as outlined above were utilized in the corresponding categories, when teachers' responses related to other categories their responses were discussed in those categories. For example, when a teacher response to the writing prompt meant to assess collaboration mentioned active learning pedagogy, this was reported under active learning. Also, when a teacher described something that fit in more than one category, those components of the framework are linked in a separate

section in results. This way, relationships between categories can be derived from the data as well as how parts of the theoretical framework work together.

RESEARCH QUESTION THREE: DURABILITY OF PD

Teacher interviews and classroom observations, conducted two years after the PD, provided data about the durability of the PD's impact. Again, the theoretical framework provided the basis of organization of results, that is, content, active learning pedagogy, collaboration, and leadership. Analysis of interviews followed the qualitative method grounded theory, where concepts were derived for each of the categories in the theoretical framework from teacher responses to the questions. Temporal cues (e.g., now, or still, or today) helped determine what data from the interviews was relevant in capturing the long-term effect on the teachers' practice and knowledge. Observations were used to look for long-term effects of the PD, comparing the self-reported data from the years of the program and interviews to the current practice of the teachers; in other words, triangulating data.

Interviews.

Interviews were semi-structured and guided by a protocol (Appendix B). Some of the questions asked were similar to those from the questions for reflection from the years of the program. This allowed for comparisons to be made, leading to inferences on the longevity of the program's effects

Observations.

Teachers were observed to gather data about their practices with detailed field notes taken; and these observations were used to the supplement the self-reported data from the written reflections and the interviews as a form of triangulation of data. The observation data was also compared to the written reflections from the PD period.

Analysis.

In reporting the results for Research Question Three about the long-term effect on teachers' practice and knowledge, the theoretical framework guided the analysis. The following describes the way portions of the data provided information on the teachers' change and its longevity.

Content.

Each of the questions of the interview dealing with content probed for teachers' view on their content knowledge gains from the program utilizing questions similar to those in the written reflections analyzed for Research Question Two as well as clarifying questions to check for consistency and longevity in teacher change from program. While conducting classroom observations, teachers' presentation of the content was analyzed for accuracy. Also, observations focused on the coverage of the content objectives and various other indicators of teachers' content knowledge and PCK were used.

Active learning pedagogy.

The questions during the interview regarding pedagogy after the PD followed up those from the PD years in the written reflections. Specifically, the teachers were asked about exploring new methods of teaching, the planning of lessons, changes in teaching, and beliefs about students' learning of mathematics. As a part of the interview the teachers were asked to expand on their responses to the written reflections and asked additional clarifying questions. Particularly the teachers were asked: "Think of your teaching during the time of the PD. In what ways, if any, did participation in the PD affect you in planning and implementing your lessons? What changes occurred in your teaching as a result of the PD? Did your experience alter your beliefs in ways students learn mathematics, and if so, in what ways?" These responses were analyzed for references indicating forms of active learning pedagogy. The observations looked for experiences facilitated by the teacher that indicated student-centered forms of learning.

Collaboration.

Teachers' collaboration after the PD was assessed through questioning during the interview. Teachers were asked for a description of how they collaborate with other teachers and the ways in which this enriches their practice. The questioning in the interview also included probing into the ways the PD changed their communication with teachers in their school and/or with other teachers involved in the PD. They were encouraged to give examples of this collaboration.

Leadership.

To assess teachers' leadership gains, questions were asked of the teachers during the interview. Specifically, teachers were asked about how they perceived themselves before the PD regarding leadership. Additionally, teachers were asked about whether they had assumed any leadership roles after the PD, either at their school campus or in presenting at conferences. The interview also asked whether the teacher had shared what they have learned from the PD with fellow teachers.

SUMMARY

In order to address Research Question One, a comparison was made of passing rate for the years before the PD to the years of the program for the schools in this study as well as four other comparable schools. In order to answer research questions two and three, a grounded theory approach was used, organized by the components of the conceptual framework. Taken as a whole, these data described what changes teachers underwent through attending the long-term PD and which of these changes continue, providing a look at the longevity of the program.

Chapter Four: Results

This chapter will report on the results for each of the three research questions in turn. Student achievement from before the teachers' PD and during the program is discussed in the section for Research Question One. Teacher change in knowledge and practice during the years of the PD is covered in the section for Research Question Two and is organized by the theoretical framework. Teachers' long-term change from the PD with data collected two years after the program is reported in the section for Research Question Three. In writing of results, the data source is identified at the beginning of each paragraph or when a new data source is mentioned; and if the source changes within a paragraph then each new statement identifies the source of data for that particular instance.

RESEARCH QUESTION ONE: PD'S EFFECT ON STUDENT ACHIEVEMENT

This research question's purpose was to check for student achievement differences attributable to the PD. Changes in student achievement at the PD schools (schools 1 and 2) were compared to changes at non-PD schools (1-4) with similar demographics, for the same years. This section will first describe the student data results and then the teachers' responses regarding other possible interventions that may have influenced student achievement.

Student achievement data.

The passing rate on the Texas Assessment of Knowledge and Skills (TAKS) (publicly available from the Texas Education Agency website) for the two years immediately before the PD period were compared to the passing rate for the three years of the program. The following table (Table 3) displays this data along with the difference of the Pre and Post percentages in a column called Change.

Table 3: Percentage of students at each school who passed the State math test.

School	Pre9	Post9	Change	Pre 10	Post 10	Change	Pre 11	Post 11	Change
School 1*	37	35	-2	36	74	+38	43	78	+35
School 2*	45	57	+12	48	60	+12	68	86	+18
School 3^	56	51	-5	51	63	+12	60	85	+25
School 4^	44	46	+2	43	56	+13	72	78	+6
School 5^	42	51	+9	44	59	+15	63	77	+14
School 6^	59	66	+7	49	72	+23	73	92	+19

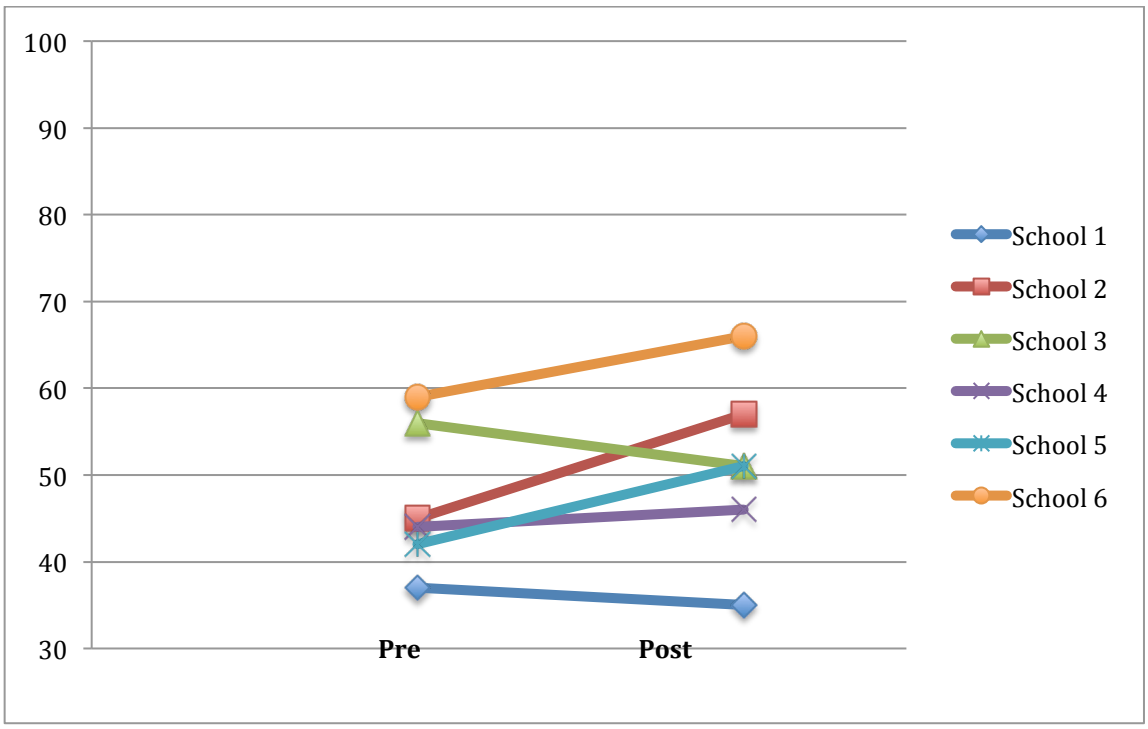
*PD schools

^Non-PD schools

School 1, one of the PD schools, had an increase of percentage of students who met the state standard both in 10th and 11th grade of 38 percent and 35 percent respectively, but

the 9th graders actually went down 2 percent. The other PD school, School 2 increased by 12 percent in both 9th and 10th grade and 18 percent in 11th grade. Some of the other comparison schools (non-PD) however had similar changes in percentage of students who met the state standard. The relatively small data set prevented statistical analysis of this change. The data are shown for each grade-level in the following Figures (2-4).

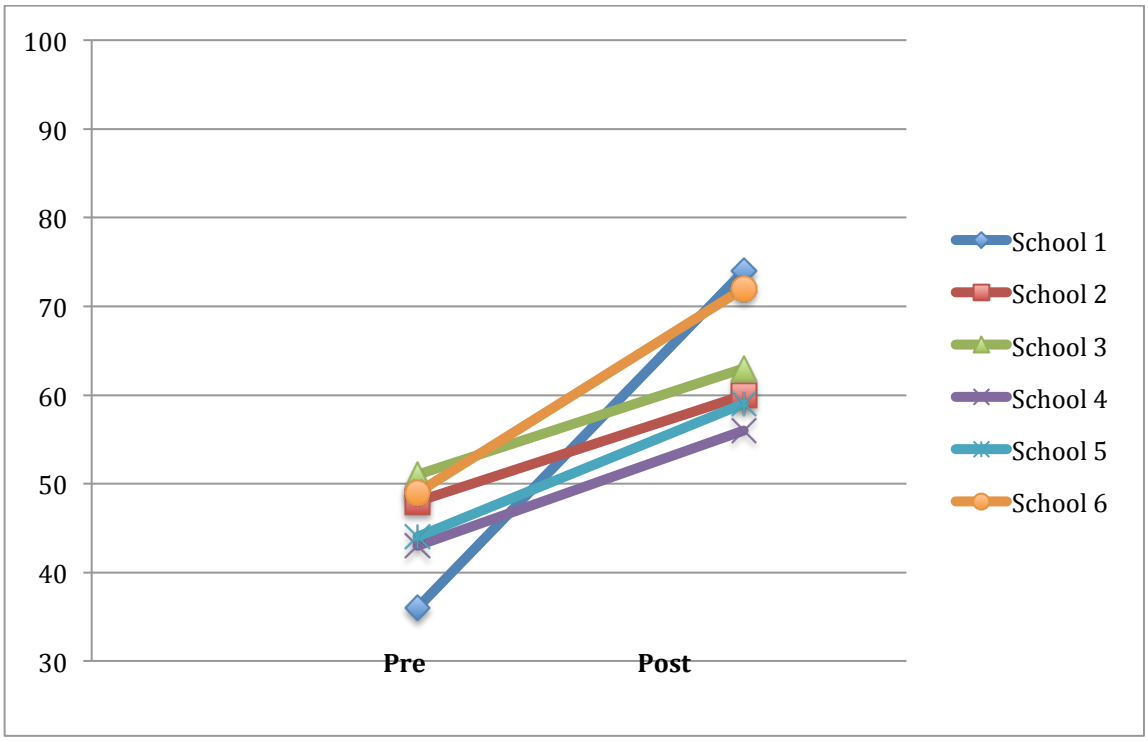
Figure 2: 9th grade percent met standard on the TAKS.



PD Schools: 1 and 2

Non-PD Schools: 3, 4, 5, 6

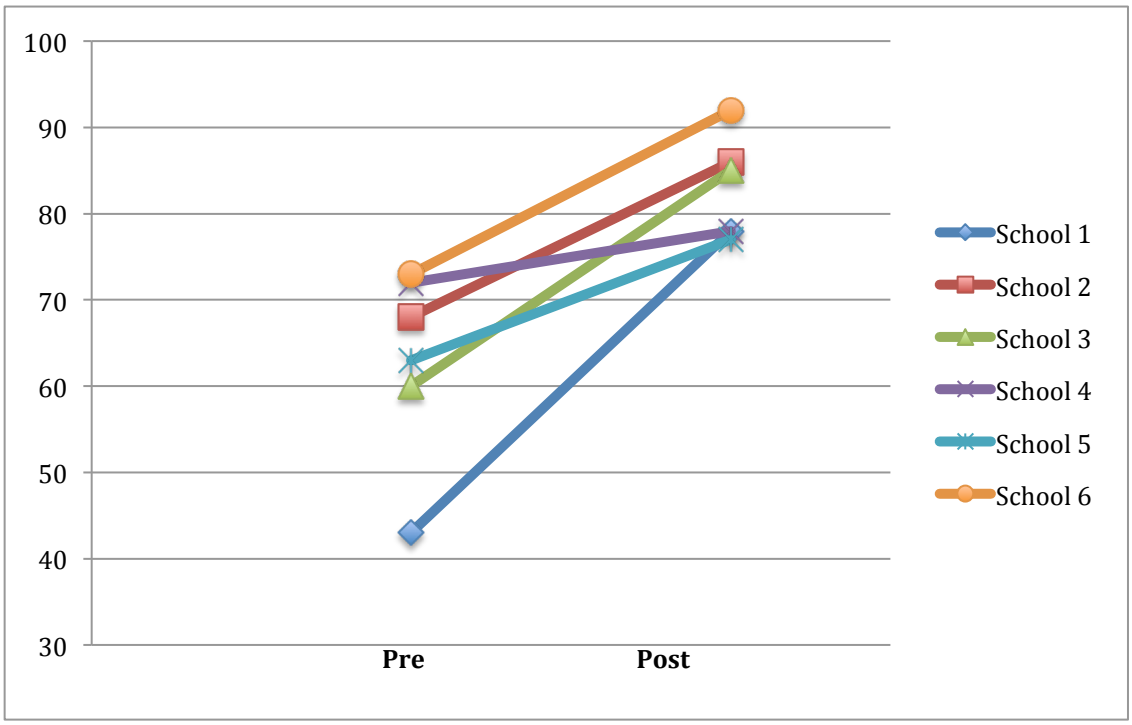
Figure 3: 10th grade percent met standard on the TAKS.



PD Schools: 1 and 2

Non-PD Schools: 3, 4, 5, 6

Figure 4: 11th grade percent met passing on the TAKS.



PD Schools: 1 and 2

Non-PD Schools: 3, 4, 5, 6

Each of the grade-levels changed from the years chosen for this study as Pre (2008 and 2009) to Post (2010, 2011 and 2012) with similar trends. The 9th grade Pre and Post data (Figure 2) were the most variable by school with two schools, one PD and one non-PD, decreasing in percentage passing and the other four schools increasing in percentage by a range of two to twelve percent. The twelve percent increase was PD School 2, which had the same teachers throughout the pre-PD and during-PD periods.

The 10th grade data (Figure 3) show all schools increasing with the biggest jump in PD School 1 of 38 percent, however the other PD school (School 2) had similar increases in percentage passing to the non-PD schools. School 1 also demonstrated the largest increase in percentage passing for the 11th grade data (Figure 4) at 35 percent, but School 2 had similar gains as the non-PD schools for this grade-level as well.

Other possible reasons for better student achievement.

Teachers were also asked in the interviews about interventions or other factors such as a change in curriculum that may have influenced their students' achievement during the years of the PD. Of the eleven teachers interviewed, nine talked about some sort of intervention or change on their campus. One teacher (T2) who did not describe any specific interventions or changes was the teacher who worked at an alternative high school. Another two (T71, T33) did not remember any interventions, although T71 did talk about a change in the curriculum.

Six of the teachers (T15, T19, T30, T51, T62, T68) mentioned their schools organized "pullouts" for the students, where struggling students received extra help. Some of the teachers (T15, T19, T62, T68) described the pullouts as a rotation for the students go to different classrooms where emphasis was put on different TEKS. One teacher (T19) explained that certain students would lose an elective and be put into two math classes. Tutoring afterschool and/or on Saturdays was encouraged as explained by some teachers (T27, T30, T62, T68). One teacher (T27), however, indicated that she

used strategies from the PD such as the use of manipulatives with students who came to tutoring. Four of the teachers (T15, T19, T30, T51) indicated that the pullouts were normally done each year for struggling students and only changed in name. Therefore, since pullouts were a constant, it is not likely that they contributed to increases in student passing rates.

Some teachers explained that interventions or changes had taken place in their classrooms. One (T27) talked about having a support person in 9th grade classes. Another (T11) explained that struggling students are difficult to get into afterschool programs, and therefore whatever intervention was done for these students had to be done in the class. Only one teacher (T71) mentioned a change in curriculum during the years of the PD and she said her school went to using an all computer-based curriculum for Algebra I. This was the only teacher from this school that mentioned this change.

In summary, there were some interventions reported by the teachers during the years of the PD. About half the teachers explained there were pullouts for students, although it was indicated in some responses that this was a normal occurrence. Also, some teachers encouraged tutoring, which from this researchers point of view is usual as well. Furthermore, one teacher described using techniques learned in the PD during the tutoring. Only one teacher described a change in curriculum. Changes in student passing rate for these teachers thus do not appear to stem from other systemic changes in their

schools. However, the gains in passing percentages were broadly similar to those at similar schools whose teachers did not attend the PD.

RESEARCH QUESTION TWO: TEACHER CHANGE IN PRACTICE AND KNOWLEDGE DURING THE PD

In order to answer Research Question Two regarding teacher knowledge changes and their own perception of practice, various data sources were utilized. The teachers' results from the "Algebraic Ideas" assessment were analyzed for content knowledge and PCK change. Teachers' change in knowledge and practice was also studied through their own written reflections from the program years, as well as interviews that took place two years after the program. The analysis of data is organized by the theoretical framework and separated in the categories of content (which includes content knowledge and PCK), active learning pedagogy, collaboration, and leadership.

Changes in content knowledge and PCK.

Teachers were assessed for both content knowledge and PCK at the beginning and at the end of the PD program using the "Algebraic Ideas" test, a part of the DTAMS. Results were analyzed for gains in teacher knowledge and a dependent t-test was utilized to test for significance. Effect size was calculated. Table 4 displays the teacher scores as well as the difference in scores.

Table 4: Teacher scores on "Algebraic Ideas" test at beginning and end of PD.

Teacher	Pre	Post	Difference
2	95	95	0
71		100	
11	85	58	-27
33	25	55	30
15	90	88	-2
19	65	98	33
68		80	
22	65	90	25
25	35	65	30
27	90	100	10
30	70	75	5
62	75	60	-15
35	50	88	38
51	45	85	40
40	40	98	58
Average	63.8	81.1	17.3

The average pre-test score was 63.8 and the average post-test was 81.1. Nine of the fifteen teachers increased their score, seven of these by twenty-five points or more. There was one teacher who stayed the same and three who decreased in score. Two teachers did not have a pre-test measurement. The Shapiro-Wilk test for normality had p-values greater than 0.05 so the data were normally distributed. The dependent t-test did show a significant increase in teacher content knowledge and PCK, $t(12) = -2.564$, $p < 0.05$. Therefore, the PD is significantly related to teacher knowledge. Since a significant difference between the pre-test and post-test was found, an effect size was calculated (Coladarci, Cobb, Minium, & Clarke, 2011) by taking the difference of the means and dividing by the pooled standard deviation, and the effect size was 0.87. This indicates a large effect of the PD on teacher knowledge.

Content knowledge change through written reflections and interviews.

Teachers' written reflections during the program years provided some information about changes in their content knowledge and PCK. The responses to the following questions were analyzed and coded for conceptual themes:

> How did the PD experience expand your depth of understanding of the concepts related to your area of teaching? How did this expanded depth of knowledge help you in your teaching? How has your deeper understanding of this content increased your awareness of the interconnection to other conceptual areas and topics?

A similarly worded question was asked of the teachers during the interview (see Appendix B), two years after the program. When examined according to the theoretical framework, teachers' responses could be conceptualized as content knowledge and PCK.

Content knowledge.

Data indicated two main themes within content knowledge that teachers described in interviews and written reflections, namely, specific topics and the interconnection of content within mathematics and across disciplines.

Specific topics.

Regarding content knowledge, four teachers specifically mentioned a change through the written reflections. One teacher (T30) wrote that the PD helped him overall on "algebraic concepts". Another teacher (T33) stated that the program helped him learn "geometry concepts and terms". Expanded knowledge in specific higher-level content was mentioned by another teacher who wrote that the PD "…experience gave me more understanding of subjects, such as Pre-Calculus and Calculus, than my many years of college. I was also given the opportunity to look at things in a different light, such as conics", which is covered in Algebra II. (T25)

Similar content knowledge gains were reported in the interviews with teachers. The teachers reported an increase in content knowledge from the program specifically in the areas of Algebraic concepts such as quadratic functions and conic sections. Teacher

T33 discussed how the program helped him understand new methods of how to factor quadratic equations. Several teachers mentioned an increase in knowledge of conic sections. For example Teacher T27 and Teacher T51 both mentioned conics when asked about content knowledge changes from the program. Teacher T51 describes:

> …it really opened your eyes to basically real conics, they way you see them in college, they way they are used in calculus, whereas the conics in Algebra II is just a brief little glimpse. So I would say it increased my knowledge of conic sections greatly….you know, now I knew, hey, this is what our kids need for college, where if you just rely on the book without the training you are not gonna get that in-depth view of it…you'll just kind of skim the surface.

This teacher realized that the PD gave him a deeper understanding of conic sections that helps him make connections and better prepare his students for further study. Similarly Teacher T40, in the writing reflections, explained how a better understanding of conics helped her make connections for students in other topics: "It has also helped me connect those skills to other topics, too, for example factoring and quadratics." Teachers like this one gained content knowledge through the program and then used this knowledge to apply to other areas they teach.

Through an interview, another teacher described an additional knowledge change brought out through the program, that is, a connection in what the name of cosine really means. This teacher described a moment where the idea just clicked and he finally

understood that cosine was “the sine of the complementary angle” and therefore named ‘*cos*ine’ (T11). Therefore, teachers’ content knowledge change from the program seemed to help them have a foundational understanding of various topics.

Interconnection of content.

Teachers discussed the interconnection of content in their responses to the written reflections, as well. Quite a few teachers (T30, T40, T22, T68, T2) described how they gained an understanding of how concepts are related and how math relates to other subjects. Teacher T22 wrote about how the program helped interconnect topics through activities and the use of technology. Expanded knowledge of how content relates across disciplines was mentioned by Teacher T2 in his response: “Relationships to non-math disciplines was also impacted as well, in science especially, but also in English and social studies. The content crosses all the disciplines. The effect has been to enhance the teaching of math for all my students.” Another teacher (T35) mentioned how the program aided him by providing activities that help to “make connections between the conceptual and the concrete”. In summary, teachers were able to see interconnections within mathematics as a discipline and connect topics in mathematics to other content areas as well, with the influence of the PD.

Teachers in the interviews also discussed this interconnection of content. Teacher T62 reported a greater understanding regarding how English skills can be fostered in a math class and the importance of this to aid student comprehension. A specific example

of a change in understanding of the way content can interconnect was described in an interview with another teacher where he discussed how there can be a bridge created, through experiences designed by the teacher, between math content and physics in using the slope-intercept equation of a line:

> …well when we teach Algebra, we always use x and y, xyxyxy…we go to physics for example you use all those other letters so the kids get lost and when you look at y=mx+b it's the same as velocity= acceleration times time plus initial velocity…You can teach those concepts together. You can use the science, get the kids used to seeing other letters instead of x and y. You can embed all that science in there. You are going to see this equation, velocity acceleration times time, that's y=mx+b, there's your slope, there is your y-intercept, this is what the graph looks like, you can tie them right together at that time and they don't see science and math as two separate classes then it becomes integrated. (T11)

This teacher gained knowledge in how to teach linear equations where students can make connections between science and math concepts. Other teachers (T19, T71, T68) mentioned making connections with science and mathematics through the program, in physics (T19), biology (T71) and in engineering (T68).

There were some teachers in the interviews (T30, T15) who reported not having any change in content knowledge from the program. These pointed out however that their knowledge of ways of teaching content was enriched.

PCK.

Some teachers mentioned an increase in specialized understanding of the way topics in content are arranged, represented, and tailored for instruction of students and their needs and interests; such knowledge is a component of PCK (Shulman, 1987, p. 8). This topic surfaced in both the written reflections and the interviews. The following themes emerged from the data: 21st century classrooms and tools for teaching such as technology.

Teacher T25, when discussing an increase in knowledge of topics such as conics in Pre-Calculus and Calculus in the written reflections, alludes to PCK gains: "…Because of my increased understanding and new approaches to these subjects, I was able to teach these things more effectively in my classroom." (T25) Another teacher also mentioned that the PD helped expand her understanding of conics and how this aids her teaching knowledge:

> I was able to get a better understanding/knowledge of how the different sections related to each other and how they were different. This helped in my teaching so I could help students develop that understanding, not just give them the information. (T40)

As mentioned earlier in the context of interconnections of math to other subjects, Teacher T11 realized that students might not connect the equations of lines using x and y in math

class to the analogous equations in Physics using t and v. This is also an example of a teacher gaining PCK.

A few teachers responded through interviews by describing a change in understanding the way mathematics is sequenced or aligned. For example, Teacher T33 stated that his expanded depth of knowledge helps him order the topics for his students so they have perspective in learning mathematics. Another teacher (T27) also mentioned how the program aided in vertical alignment of concepts. Also teachers T33, T27, T68, and T11 discussed gaining insights related to the structure of the TEKS or standards that they need to teach. For example, Teacher T68 explained: "I got a much better grasp of even the structure and then learning those standards and learning the TEKS… during the [PD]". Similarly Teacher T27 also increased her knowledge of the TEKS: "That's one of the things we would do is study the TEKS and how to present, how to demonstrate, you know." So the knowledge of how mathematics is ordered and organized for students was increased for these teachers.

Teachers reported in the written reflections that they gained new ways of impacting students (T35, T2, T25, T19) For example, Teacher T35 wrote: "Learning different ways to teach the same concept helps in differentiation for our students. This also helped in deepening and broadening concepts taught." Teacher T2 responded that the program provided an increase in knowledge through activities and "group work in systems of equations". Another teacher (T11) wrote about how the program helped them

meet needs of students who were “at-risk”, while a different teacher (T25) similarly described how he learned “new ways and approaches to teaching students” according to their different ways of learning such as “some approaches or methods work better for visual learners as opposed to kinesthetic learning”. (Although teaching according to specific learning styles is questionable according to research (Pashler, McDaniel, Rohrer, & Bjork, 2008), it is still encouraged to utilize multiple representations. According to Coffield et al. (2004) “there is a substantial body of research which points to the instructional value of using multiple representations and specific devices such as graphic organizers and ‘manipulatives’”, where gains in learning were found for the general use of these methods (p. 14)).

Teacher T51’s written reflections described his knowledge gains concerning ways to engage students by having them “explore and investigate their own math ‘challenges’”. One teacher summarizes the way his knowledge changed concerning the ways students learn as follows:

> I received valuable PD, training, technology to use in our classroom, great activities, differentiated instruction tools and more. I am now very well prepared to be in a classroom with all the tools to be a better teacher than I was. I am using higher-level instructional strategies consistently and seeing the difference in students’ behavior and leaning capabilities. (T19)

This teacher seemingly increased in PCK regarding strategies and ways to use tools in order to better impact student learning.

Teacher T33 mentioned in the written reflections that he grew in the understanding of state assessment changes and how to further provide his students with ways to face these assessments. For example, he described, "We studied different end of course exams from the states to come up with our own test questions which can be incorporated into the classroom teaching" (T33). Therefore, this teacher grew in providing assessments more in line with student needs. Additionally teacher T40 learned it was necessary to find student-centered activities in order to help students prepare for new requirements in state assessments as seen in his written reflections. Teacher T62 mentioned the resources prepared during the PD for new state assessments in her interview, as well.

A very common response in the interviews by teachers was an increase of understanding regarding ways of presenting content for students. Nine of the teachers (T11, T19, T27, T30, T33, T51, T62, T68, T71) mentioned this impact on their knowledge. Teachers felt that the program enabled them to break down the content into chunks that were more easily understood by students. One teacher (T11) stated:

> …it helped me realize that students at that level need the content broken down into the simplest pieces… Although I was expert in content already, I became an expert in simplifying the content to make it understandable for the student.

Even though this teacher felt like he knew the content well, the PD aided his understanding in ways of breaking down content. The breaking down of content into pieces was mentioned by several teachers (T11, T68, T62) in that they understood better what pieces of content were essential for students to learn. Similarly a different teacher reported that she learned "how to relate certain math concepts to people who are learning it for the first time" (T71), and another felt like he gained knowledge in presenting content "at the student level" (T51). Teacher T68 spoke about how the program aided her understanding of common mistakes students make. She explained it this way:

> …learning what students have difficulties with and then getting some strategies of things to try because this is kind of where they go. So a lot of times we were discussing during that collaborative we would say, "Well, students tended to think this way. This is the mistake they are going to make…"; realizing, finding some pitfalls and then knowing what to look for and what to expect (T68)

This teacher gained knowledge in ways students look at certain concepts and predictable errors students can make. Teachers therefore increased their PCK relating to students and ways they learn content.

21st Century classrooms.

The data contained in the written reflections showed that the PD helped teachers think about how to modernize their classrooms. Teacher T11 described "the program brought my classroom into the 21st century", and this phrase provided the *in vivo* code for

this common theme in teachers' responses. Another teacher (T25) stated that this PD "has given me a new perspective on teaching". Several teachers (T15, T27, T40, T25) reported on how the program updated their teaching methods and how the program allowed them to try interactive strategies in order to engage students rather than teaching more conventionally. Teacher T40 summarized the change this way:

> I have learned that the "same old way" that I have always taught is not what my students need today. The students today need to have a higher learning skill and be able to reach a higher level of thinking. They need to be challenged to reach out and apply what they have learned. I must keep growing too so I can help that to occur.

This teacher believed that growth in his practice helps meet the needs of the students of this generation. Similarly, another teacher explained:

> It helped me by showing me that teacher-based teaching is not working and gave me techniques and technology to change to student-based. It showed me that the students of the future are going to need technology to help them learn concepts we took for granted. They are a more visual generation. They need to see the overall math and how it is connected rather than just working with algorithms with no knowledge of why they are connected. I now need to plan my demonstrations with visuals in mind. Calculators are my strong suit and I use them to show how different concepts are connected. (T30)

This teacher described a change in his practice from teacher-based to student-based in order to meet the needs of "the students of the future". Another teacher (T51) used the phrase in his written reflection "modern approach to classroom teaching". Teacher T27 summarizes, "Growth took place in each of us throughout our time together, from teaching old school to upgrading our teaching methods…" The PD seemingly was the catalyst for teacher growth in practices in order to meet the new challenges of students of today and of the future, working to create classrooms for the 21st century.

Tools for teaching.

Another teacher (T30) wrote about how the program increased his knowledge of pedagogical tools for teaching of content such as "foldables and calculators to assist students in their learning" as well as "a knowledge of technology". Foldables are a variety of paper folding "techniques that can be used to integrate reading, writing, thinking, organizing data, researching, and other communication skills into an interdisciplinary mathematics curriculum" (Zike, 2003, p. v). Similarly, teacher T62 responded, "I've expanded my knowledge in using manipulatives, and Nspire calculator". In fact, multiple teachers (T30, T22, T2, T35, T51, T62, T19, T11) wrote about the technological impact to their knowledge. Several teachers described learning different forms of technology that enhanced their practice. One teacher (T68) wrote about training received on the use of the Promethean Board (a type of interactive whiteboard) and the TI-Nspire calculator; he said that the "incorporation of technology has greatly enhanced

the classroom experience of my students". Other teachers wrote about how training on the calculator aided them in changing their teaching as well. As described in the previous theme, Teacher T30 believed that technology helps him reach "the students of the future". Another teacher stated that the calculator benefited students with visual or kinesthetic learning styles, aiding students to solve complex problems through the use of "graphic and tabular interpretations" and that "special calculator programs greatly simplified higher-order thinking skills for them" (T2). This same teacher also mentioned how the program aided his lesson planning through the use of technology such as the SMART Notebook, a type of software for use with an interactive whiteboard useful for teaching. The SMART Notebook helped this teacher to "capture" and "link" curriculum, photos, and videos in lessons. Additionally, teachers T25 and T27 mentioned that the use of more technology, during the PD, aided the planning of lessons and projects for the classroom. Teacher T27 described how the program helped her find websites that aided in engagement and demonstration as well as updating her teaching methods. This same teacher mentioned that the PD provided technological resources that could not be provided by the school campus and that this really helped her to grow as a teacher. Other teachers (T62, T2) also described how the program provided calculators, laptops, and software for use in the classroom, as well as suggesting ways to engage students while using this technology. Teacher T19 summarized, "I learned so much and tried to apply in

my classroom all the available technology to the research-proven teaching strategies." In sum, teachers grew in PCK in the use of technology.

The interview data also showed teachers improving their understanding of technological tools for teaching. Several teachers (T33, T62, T27, T71, T30) mentioned that the program aided their understanding of technological tools and allowed them to build student understanding of calculators and various types of interactive whiteboards. For example Teacher T30 explained, "It was mostly how we can use technology…to better assist the students with their knowledge". Additionally, teacher T33 learned how to use a SMART slate and said the PD enabled him "to become more technology savvy". Teachers (T33, T30, T27, T62, T71) talked about ways they used technology learned from the PD to facilitate student engagement. For example, teacher T71 explained: "…it's not as if I didn't believe in engagement before – it's just I didn't really feel like it was as important on a technological basis as I did after I saw all the possibilities". This teacher discovered that technology such as TI Nspire calculators and using cell phones as a personal response system to answer questions posed in class were powerful ways to engage students in learning. Increased knowledge about the use of these tools augmented the teachers' PCK regarding engaging students and in multiple representations through the use of technology.

Active learning pedagogy as evidenced in written reflections and interviews.

Teachers responded in writing to the following question, during the PD years: "How did your PD experience impact your thinking about teaching and learning? Discuss how these ideas helped you plan and explore new teaching methods as a result." Teachers' responses to other written reflections were also examined for data regarding active learning pedagogy. Similar and related clarifying questions were asked in the interviews, two years after the PD. The teachers' responses to written reflections and interviews were chunked into themes. Teachers wrote about and discussed two main areas: ways of promoting active learning and reasons supporting the use of active learning.

Ways of promoting active learning.

Teachers' responses indicating a change in promoting active learning were chunked into two themes: describing forms of activities they utilized and detailing ways of creating opportunities for students to be accountable for their own learning.

Activity forms.

Many teachers (T2, T15, T19, T25, T27, T33, T35, T40, T51, T68) mentioned the word "activities" in their responses both in written reflections and in interviews. In a written reflection Teacher T40 described his need to implement "student-based activities and activities…[to help] students remember the information over time".

Many teachers described in interviews (T11, T15, T19, T27, T30, T33, T62, T68) and in written reflections (T27, T68) some activities that they used in their classrooms. Some activities mentioned in interviews were bungee jumping activity, tennis ball activity, word posters, group activities, experiments, projects, hands on, games, scavenger hunt, use of manipulatives, calculator activities, and activities related to "STEM" (Science, Technology, Engineering and Mathematics). In written reflections the tennis ball activity, bungee activity, projects, games, experiments, and the use of manipulatives were again mentioned, and additionally students' use of laptops, a Ferris wheel activity, and a create and color activity. These are described further below.

Additionally, teachers in interviews (T62, T68) and in the written reflections (T25) talked about having students do projects. Teacher T68 discussed in her interview that projects "took it out of 'mathy', let's just do some formulas type thing, but to really implement and do other things…". Games were also mentioned by teachers in interviews (T19, T62) and in written reflections (T27, T51) as a means to promote active learning of students.

Teachers understood that activity for activity's sake is not enough; activities need to support learning. Teacher T19 explained in his interview that he makes sure the students can make the connections to why they are doing an activity. He said:

> …a lot of times when we did the activity in my school the first couple of years all the students were all really happy about "oh, yeah, bungee jumping" and all that.

> And that's it. They don't know why they were doing it for. And the math part comes and they'd stop working right away. You know all their zest goes away so that helped me kind of connect that, to anticipate, ok we will do this, we will do this, we will do this, keep telling them along the week and be able to bring them to the level where they will understand, "ok, what we learned here, we did this and this, that's why we did this". So I think that's one thing we did in [the PD] in a loosely way…(T19)

This teacher felt like he was doing activities where students learned concepts and the students were able to understand why and how this was applicable to mathematics. Another teacher (T68) talked in her written reflection about having students explore quadratic equations through a tennis ball activity that she did while being observed by her principal, referring to the state system for annual teacher evaluation called the Professional Development Appraisal System (PDAS):

> I would say the biggest difference for me having participated [in the PD]… has been in my confidence to try different approaches and various lessons. In fact for my PDAS review I used a lesson that was introduced during the summer. I was confident enough to have my students do an experiment with a tennis ball and food coloring to write quadratic equations. Before my experience … I was too intimidated to try such things on my own, let alone in front of the principal. (T68)

This teacher felt like the PD enabled her to have confidence to try the activities such as the tennis ball activity in her classroom. Another teacher mentioned in his interview first experiencing the tennis ball activity in the PD and then having his students do the activity as well:

> …Like a hands on one, I think it was with the parabola and we had the tennis ball, we dumped the tennis ball in like, like uh…dye color…food coloring… Yeah, we rolled the ball and you know and we brought that into the classroom and did it with the students…yeah, I guess you like graphed it…you know you found the vertex … (T33)

Teachers like these were empowered with the knowledge and background to make connections for students in order to provide learning activities where students could experiment with mathematical concepts. One teacher (T19) summarized the overall trend: "it (the PD) just made a great difference in my classroom" because " I started using a lot of activities and techniques I learned".

Teachers discussed other ways of promoting active learning for students in their interviews. One teacher in an interview discussed having students work through a scavenger hunt:

> …the one I can specifically recall is 10 problems or 15 problems around the board and they do a problem, they get it right and that number sends them to the next

problem… And they have to get back to the beginning in some sort of…[scavenger hunt]. (T15)

Through the scavenger hunt activity, this teacher helped his students take control of their learning by helping them work toward answers, which led them to the next problem to be solved. Other teachers mentioned games in written reflections (T27, T51) and interviews (T68) as a way of having students actively participate in math. Teacher T68 talked about games based on standards in her interview, while Teacher T27 wrote about a game utilized in class, which was put together in the PD, based on created questions for standardized tests.

Having students work together in groups was another strategy that teachers now implemented. One teacher talked about the change brought about from the program: "…give the kids opportunities to participate in classroom, work in groups…the group thing is probably the biggest change, getting these kids to collaborate, working together...to get them to talk things out…how do you solve the problem" (T2). This teacher mentioned utilizing groups in his classroom both in the interview and in his written reflections. However, this teacher was not available to be observed since he worked in an alternative school so this assertion was not verified via observation. Other teachers who mentioned using group work were Teachers T51 and T62 in a written reflection, and Teacher T11 in interviews. Teacher T51 explained in his written reflection that the PD enabled him to know how to group students. Similarly Teacher T11 talked

about the importance of the structure of groups of students, collaboration within the groups, and how to make individual students accountable in the groups.

Individual student accountability.

Teachers mentioned in both written reflections and interviews how they were creating opportunities for students to explore and do mathematics for themselves. For example, Teacher T33 discussed in his interview utilizing interactive whiteboards at students' desks to have them share work or bringing work to a document camera: "…letting students come up to the [document camera] and working problems out… letting them write on the [interactive whiteboard], you know at their desk…uh… just being more…just get their interest, their motivation…". In his interview, Teacher T51 also mentioned using document cameras to have students actively participate:

> …the document camera just opened up the student's responses … I could just say bring your paper here and put it in the document camera and ask the student explain your work and the students can come teach and stuff… and I could assign different problems to different students and have a little team around them to help them with those problems and then show the work on the document camera. (T51)

Another teacher (T27) described a similar way to make students accountable for their own learning by having them work through problems on a whiteboard: "I would have what was called little workshops if they didn't understand and then I would set them aside at a whiteboard and then we could go through it." A different teacher (T71)

described in her interview how she would have students actively participate by responding to questions by texting with their cell phones as well as the importance and the power of student engagement through having students participate in this manner. Teacher T62 mentioned in her interview another way to keep students accountable for their learning; they kept a journal where they reflect on and organize their work. Similar tools were used by Teacher T30, who talked about the use of Foldables to help students make sense of mathematics in his interview and written reflections. This same teacher described in a written reflection another method he used for facilitating student accountability: "I look for worksheets which make the students take the initiative and learn on their own or with a partner." (T30)

Reasons for active learning.

Teachers not only provided evidence that they now promoted active learning pedagogy for students; they also mentioned the reasons for doing so. Teacher T30 wrote that the PD "gave [him] foremost an understanding that the students must take an active role in their learning" and "that teacher-based teaching is not working and gave me techniques and technology to change to student-based". Similarly, Teacher T15 described in a written reflection that the PD "opened my eyes to other, more interactive methods that steer away from conventional teaching methods". Another teacher, who talked about how he changed to be very *non*traditional in his teaching in his interview, mentioned in a written reflection that he "learned to tie student engagement to the

learning process". Teacher T62 described in an interview why she incorporated active learning pedagogy: "…hands on because students get bored if you just give them worksheet after worksheets. They have to learn by actually doing it…". This teacher therefore understood the importance of student interaction in the learning process. Another teacher (T27) explains: "I did a lot of hands on that particular year so that they could make their connections…" This teacher further mentioned that she believed that this helped her students' achievement improve:

> Scores of course have increased and I think its because of the sharing piece where we were able to obtain different ideas and perspectives on activities as they pertain to many of the state TEKS and um so it…in the program the greatest part of it was hands on, which our children need quite a bit for better understanding and so I was able to take all of that and bring it into my classroom and use it so that was the biggest piece right there. (T27)

This teacher described that her students did better because of what she implemented from the PD, as well as how this helped her facilitate active learning based on the state standards. These teachers were conscious of their rationales to promote student activity and engagement.

Projects as a form of active learning, as mentioned earlier by Teacher T68 in her interview, provided opportunities that were less "mathy" than just working with formulas; this enabled her students to have confidence. Games, described previously,

help all students succeed even those with little parental support or who are not motivated to learn, according to Teacher T19:

> …The problem is those who kids who aren't either smart enough or aren't trying or the kids who can learn but they don't have the opportunity to learn anything so you know their life afterschool or outside the school time so it is not important to them. So I think in that sense the engagement part is important and everybody gets engaged if you play a game or do an activity or something like that and connect that to some math concept is helpful. (T19)

This teacher realized that active learning pedagogy provides a way of motivation to learn for students. The creation of posters for words as described previously, helps create "meaningful ways of exploring vocabulary" (T11). The value of particular projects or activities for students was described by these teachers.

In summary, teachers described the use of many activities with their students such as projects, games, interactive whiteboards, and posters. These provided students with opportunities to experience mathematics for themselves. Teacher T11 provided an informative summary of active learning in his classroom through a response in his interview when asked about changes in his teaching due to the PD:

> Far less lecture. When I went into that job, it was very traditional classroom. My classroom now is very *non*traditional…I do lots of groups. I do lots of stations. When I say nontraditional its more what the middle and elementary people do.

> Um…I do very little, very little lecture…I do more exploratory learning…I do a lot of student collaboration learning…uh we find ways of alternate assessing…you know demonstrating mastery but not necessarily on pencil and paper. Those are all things that I wouldn't have done prior to having this experience. (T11)

Teachers seemed to change their focus from teacher-centered to student-centered through various ways of promoting active learning.

Summary of results for active learning pedagogy.

Through written reflections and interviews, teachers described how their understanding of active learning (in terms of both forms and rationales) changed during the years of the program. Most teachers talked about a move from teacher-based to student-based pedagogy and talked about reasons this benefited their students, and many discussed promoting individual student accountability.

However, one teacher (T15) struggled with identifying changes in his practice for most of his interview. This teacher said things like: "I tried some of the activities that they presented…I don't know of any major methods change…" He explained that he felt bounded by the curriculum at his school and did not feel he had the freedom to change or implement practices from the PD. He did remember doing a scavenger hunt activity as mentioned previously, but overall reported little change. This teacher's report or remembrance is not consistent with the assertions made by the math department chair of

this school, Teacher T11, who stated that the PD had a strong influence on the math department at the school and talked about how student-centered practices were emphasized by his leadership.

Collaboration as indicated through written reflections and interviews.

Teachers' responses from written reflections during the PD provide insight into what collaboration was like during this time as well as the benefits the teachers described. The teachers were responding to the following question: "Describe how you communicate and collaborate with your fellow PD teachers between PD sessions? How do or could these collaborations enrich your practice?" A similar question was asked in the interviews as well. Teachers discussed their collaboration throughout the interview, as this was a major part of the PD; in fact "collaborative" was in the name of the program. The themes surrounding the discussion of collaboration are communication forms, benefits of collaboration, and collaboration problems.

Communication forms.

Through the written reflections teachers described on-campus meetings ranging in frequency from daily to two to three times a week. Some teachers collaborated at school-organized meetings such as "math collaboration periods", "common lunch times" or "district meetings". Some teachers met during lunch, some after school, and some got together for coffee. Most teachers expressed that their collaboration was mainly with

those in the PD who were on the same campus. One teacher did describe a time when another teacher from a different school came after school in order to demonstrate how to use a specific form of technology. The teacher explains: “On one occasion another teacher came to my campus after school to show a group of us how to program Promethean board so the students could use active expression on a self-paced assessment.” (T68).

Teachers also mentioned, in the written reflections, that collaboration was done electronically. Email was mentioned many times as a way to communicate with teachers from the PD, whether they worked at the same campus or not. Of the fourteen responses nine mentioned email as a way to collaborate with other teachers from the PD. One teacher mentioned communicating through a message board and another mentioned using the videotelephony program “Face Time” in order to collaborate. This teacher explains: “I have face-timed certain teachers so that they could show me how they would teach certain lessons.” (T62) Additionally, phone contact was mentioned by this same teacher as a way to collaborate. She considered it a “luxury” to have cell phone numbers of colleagues from the program and permission to call for help.

In the interviews, the teachers described the times they met to collaborate as well. Some teachers (T11, T30, T27, T2) mentioned that collaboration with other teachers was a weekly or even more frequent experience. Teachers (T2, T11) talked about how they

would meet up in the hallway between classes to discuss what was working or not working in their classrooms.

Teachers described in the interviews their collaboration with others both within their school and out of school. Some (T33, T30, T51, T15) commented that the bulk of the collaboration they did was within their respective schools with a few of these (T15, T33, T30) saying that was their only collaboration with other teachers. The program enriched and increased collaboration within schools for some of the teachers (T2, T33, T19, T11). In fact one teacher (T11) described the PD as changing the culture of collaboration on the campus. Another teacher (T33) described the PD as way to get to know teachers at his own school and said it made it "easier to talk to them…so it kind of carried over into the school". Other teachers did not have that continuing beneficial experience of collaboration as they felt like they did not have the freedom to change the curriculum (T15) or at times worked with other teachers who felt this way (T27).

In data from the interviews, regarding collaboration outside their respective schools, some teachers (T62, T71, T19, T68, T11) felt like this provided a way to share with others with a different mindset so they could be more open to new ideas. One teacher explained when she worked with just the people who were in her district or school she felt,

> you still are working with somebody under the same roof and with the same resources to work with and with the same sort of tradition of "this is the way that

> we do things" and what I learned from all of the other teachers in different districts……the difference in perspective… it broadens your scope definitely talking to a variety of teachers…without assuming that the baseline was the same for everybody was very helpful (T71)

The PD provided a collaborative environment for this teacher that allowed her access to teachers who were from different schools and thought differently, and this helped broaden her teaching. Most teachers felt like they collaborated more within their respective schools and found that the program aided this collaboration. Some teachers found that the PD helped them communicate with teachers outside of their respective schools and this enriched their practices.

Benefits of collaborating.

Data from the written reflections indicated multiple benefits from collaboration in the PD. One way teachers benefited was in sharing resources and experiences with other teachers. Teachers wrote in the written reflections about sharing ideas for lessons, data, electronic files, as well as the implementation of these. Teachers saw sharing resources as a major part of collaboration. Another teacher (T27) explained that what "impacted my teaching and learning the most was the sharing among teachers". Other teachers (T2, T62, T35) responded about teacher sharing. Teacher T35 wrote, "By bringing together teachers from all experience levels from different schools it provides one with different perspectives and resources" and "activities compiled over the summer provide me with a

great amount of different resources". Teachers mentioned in interviews that they felt that through the collaboration they gained resources for teaching such as activities, games, and Foldable ideas. For example one teacher stated that her student scores had increased, and said, "I think it is because of the sharing piece where we were able to obtain different ideas and perspectives on activities as they pertain to many of the state TEKS"(T27). One teacher described in the written reflections, the use of electronic file sharing as resources that she could pull out at anytime (T27). Other teachers (T11, T62, T71, T68) described collaboration with teachers much like Teacher T19 did in that they were able to share strategies that worked in their classrooms as well as give and receive feedback regarding those strategies.

Another theme was work reduction. One teacher said, "communications help to reduce the individual workload and provide teaching ideas I might not have thought of myself"(T2). Teachers T27 and T19 stated that collaboration reduced their isolation and allowed them to share the workload as well.

Teachers shared by providing feedback to one another, as well. One teacher described feedback as critical (T25) and this feedback centered on whether certain practices were beneficial and whether any adjustments or improvements were necessary.

PD teachers also described sharing ideas and resources from non-PD sources. Teacher (T62) mentioned in the written reflections that the program allowed him to attend conferences and training that he otherwise would not have been be able to afford.

Teachers T2 and T19 also wrote about resources gained by attending various conferences. One teacher explained, "I was able to attend many of the prestigious math & teaching conferences, attended several valuable PD workshops and was able to learn & implement that knowledge within my classroom" (T19). Teacher T2 explained that not only did he benefit from what was learned through the lessons learned through the conferences but that other teachers at his school also benefited. This teacher stated, "I was able to bring fresh ideas into the classroom and also share these ideas with…colleagues" (T2). Teacher T19 also mentioned that he used "the valuable resources and the opportunities provided" to mentor other teachers. One teacher (T29) commented that different techniques were learned from others so that student learning was more attainable or interesting.

Data from the written reflections indicated that another benefit of collaboration lay in addressing the needs of students. Teachers (T19, T62, T71, T2, T11, T30, T68) felt that collaboration aided them in ways to reach students, as evidenced in interviews, Teacher T11 mentioned that student issues were discussed. Another wrote that collaboration focused on sharing "ideas and strategies that are beneficial to the success of our students" (T25). Teachers T27 and T71 believed that their growth in practice took place through contact with other teachers in the program who "came together season after season" (T27) and who "were concerned with improving but knew first-hand how to deal with the things we deal with". Specifically, one teacher said that in collaborating they

focused on special populations of students including those who perform poorly and language learners (T51). One teacher stated that the PD "experience has taught me the importance of collaborating with fellow teachers to maximize resources to better address the student needs" (T22). Teacher (T19) described how collaboration helped him work through common problems:

> …most of us had common problems too so we had a chance to discuss about it then you know what that's what happened in my class and couple say yeah I had the same problem and third or fourth person would come in and say, "you know what, I had this experience and why don't you try this", and we learned from each other and so that was a good thing.

Additionally, in data from the interviews, one teacher (T19) reported that the PD provided a place for teachers to learn how to collaborate. Another teacher (T62) found that the program put her in contact with teachers who were experienced and this helped her grow. Another responded in written reflections that collaboration aided in growth and learning as well (T19).

Collaboration problems.

Teachers wrote in the written reflections that communication was often insufficient and felt that they needed to communicate more regularly. One teacher in particular recalled that teachers from the campus where she worked moved away and how this led to the feeling that she was on her own (T27). Another teacher said that he

wished he could learn more from a fellow PD teacher that he viewed as innovative (T30). One response indicated that an increase in "communication would have been beneficial based on the communication when we do meet" (T35).

Teachers also discussed issues regarding collaboration. Teacher T27 explained in her interview that teachers in her school just "wanted to do their own thing. They were stuck in that mold…I wanted to teach them how to collaborate, how to work, so that the job doesn't fall on one person. But they couldn't." She also explained that some of the teachers wanted to follow curriculum as recommended by the district rather than try new approaches, and this curtailed collaboration. Another teacher (T15) felt that he did not need to collaborate during the PD because,

> …I was doing my own thing…I know what I wanted to show them and it was nice and I was able to do that and there was some collaboration, if someone was also teaching PreCal and they wanted my opinion. I didn't necessarily go to anyone. I knew the content. I knew what I wanted to show them and how I wanted to present it. (T15)

This teacher did not perceive a need for collaboration for himself because he had a set agenda for teaching his course, but was willing to share with others if they asked for help.

Summary.

Teachers' responses during the years of the PD show that collaboration was either in person through formal or informal meetings, or electronically through email,

videotelephony, or over the phone. These collaborations were beneficial to teachers as a way to share ideas for lessons, the gaining or giving of feedback, workload reduction, and to improve ways of addressing the needs of students. Nevertheless, some teachers did felt that collaboration did not happen often enough, felt it was unnecessary, or described obstacles to collaboration.

Leadership.

Teachers had gains in leadership as evidenced in the written reflections and interviews. Changes took two forms: as defined under the traditional conception of leadership with positions where they provided mentorship or guidance in leading others and also as confidence as, "a stance, a mind-set, a way of being, acting, and thinking as a learner within a community of learners, and as a professional teacher" (Darling-Hammond et al., 1995, p. 95). Therefore, teachers' description of this change was outlined in this manner: confidence in being a professional teacher and acts of leadership.

Confidence in being a professional teacher.

There is evidence through teacher interviews that leadership was fostered in teachers during the PD through gains in confidence. This helped Teacher T68 feel that she was more experienced. Another teacher (T33) also was aided by working with other teachers in the PD. When asked about gains in leadership he first exclaimed that he was "about the same" but then he elaborated:

> …usually the groups that I was with were kind of like the leaders…you know so I kind of like…I guess I was a follower…no I didn't…I don't know how much it helped me to…but I guess it did in a way because of just the interaction with other teachers…kind of helped you gain confidence or something…so maybe in that regards. (T33)

This teacher explained that he now had more confidence because of working with other teachers through the PD.

The responses in the interviews revealed a growth in confidence in other ways as well. Teacher T27 mentioned that she "matured as a teacher" and that the PD helped her grow in her methods. Teacher T19 described: "…I had more confidence…to try new things which I would have thought, 'Well, I don't know if I should do that or not. I've never seen people doing this', and so forth. That was a big encouragement…" Another teacher, who lacked a math background, also talked about the way the program gave her more confidence. She explains:

> …about confidence, it's just that I had confidence to try more things and try things that maybe I was more comfortable with. I don't have a math background; I don't have a math degree…um but math is just very…it's always been just very easy for me. I'm more a logical person than math person in all honesty…um so it goes back to the confidence. So I could try some things that I…because I had a better understanding in general of where the students were and where they were

> going, I could try some things that were a little less "mathy" but a little more common sense and I could also encourage my students and you know what, you guys kind of know this. We've been doing it this way; you know you're just thinking its different now because of the variable but you can do it and those type things um…I do feel very much that it freed me up to try some different things or maybe even just more willing to just be myself in it… (T68)

The program enabled her to try new things in her classroom because she gained understanding and therefore had the confidence to lead in instructional innovation. Similarly, Teacher T71 described that the program aided her "ability to teach" because she had more confidence.

In responses from written reflections it was evident that teachers grew in confidence in their teaching as well. Teacher T19 described how being in the program helped him as a new teacher and furthermore "the support and confidence I gained over the years…was astounding". Confidence gained through the program helped teacher T25 overcome challenges in her classroom as well. Teacher T68 said that the largest impact of the program was confidence to plan and implement lessons as described earlier in an excerpt from her written reflection in the section for active learning. Another teacher (T51) wrote that he "continues to grow more confident in [his] ability to teach". Teachers gained confidence through the resources and experience gained in the PD that reportedly changed their practices. The confidence gained enabled them to grow more professional

as teachers, fitting the alternate definition of leadership developed by Darling-Hammond and colleagues (1995). In other words, the teachers developed a leadership mind-set through confidence in their ability to teach.

Acts of leadership.

As part of the PD, teachers were required to present at the state-level teaching conference. One teacher (T51) mentioned presenting in the interview; he/she recalled sharing with other teachers what he had learned in the PD. A few teachers (T2, T11, T27) also provided evidence that they took what they learned in the PD and shared it with others on their respective campuses, through responses in the interviews. Teacher T2 described his mentoring approach to new teachers through sharing lesson plans and meeting with the teacher regularly or between classes in the hallway. A math department chair (T11) discussed how he trained teams of teachers at his school: "that [PD] really helped us bring things that were…that were current that were based in research, that were best practices and we could bring those directly back in the classroom, train our teams and then audit them". In contrast, one teacher (T15) did not initiate contact with other teachers to share what he had learned, displaying a missed opportunity for leadership, as described previously.

In summary, teachers grew in leadership during the PD resulting in confidence and experience, that is, becoming more professional in teaching, and exhibited leadership in sharing with others at conferences or at their own campuses.

Integration of multiple components of the theoretical framework.

During data analysis, various instances were detected in which teachers described multiple elements of the theoretical framework working together. Integration of multiple components was thus an emergent theme. These data can provide insights about mechanisms by which the components of effective PD actually effectuate change, and are discussed at length in Chapter Five. The interviews and written reflections were reexamined through the process of axial coding (Corbin & Strauss, 2008) for types of interaction or integration. The following section describes evidence of how content, active learning pedagogy, collaboration, and leadership interacted with each other during the PD for teachers.

Content and collaboration.

Some teachers wrote about how collaboration supported content knowledge changes. According to the responses from the written reflections the program provided the place for collaboration and exchange of ideas related to what was taught for many of the teachers (T2, T11, T15, T19, T22, T25, T27, T30, T35, T51, T62, T71). One teacher (T27) described a greater understanding through collaboration on specific content related activities like “the Bungee activity or the Ferris wheel” and “a bank of questions” for use in the classroom. The constant exchange of ideas from teachers in the program was a major impact to the knowledge of teacher T2 who wrote that the collaboration with

teachers in sessions provided a way of "expanding on best methods to explore and explain concepts". The collaboration influenced the PCK of another teacher who wrote:

> … having a network of teachers available to answer my questions or provide much needed resources. I remember just this year calling my colleagues at least four times to ask them how they would teach a certain TEKS to get the best student engagement and have the student remember the lesson. I am so glad to have that at my disposal …(T62)

This teacher describes the collaboration in the program as being integral to their knowledge change. The responses of multiple teachers (T2, T35, T62, T11, T51) indicate a change in PCK through collaborations with other teachers where sharing of the different ways students learn content was fostered.

The data from the interviews exhibited the connection between content and collaboration, as well. For example, Teacher T27 discussed that collaboration with other teachers aided her study of the TEKS. Another teacher described how her knowledge was enriched:

> …I think that my knowledge of pedagogy was definitely expanded um mostly because of just the interaction with the teachers that were in the program um and also definitely interesting ways to use technology in the classroom. I definitely started to look differently at cool little things you can do with TI Nspires or with the text-in answers to quiz question thing or the um Agile mind has the clickers

> response thing because I think there were so many teachers that had to use the same materials it was a really good place to…I don't know what it was about [PD], but it was just a much better collaboration place than meetings…as far as what sticks out in my memory of improving my knowledge I think that would be the biggest area. And then the second would be just in um…not in math concepts but in how to relate certain math concepts to people who are learning it for the first time…talking to teachers from other districts in the [PD] helped me with that too. (T71)

The PD provided a place where this teacher could collaborate with other teachers and increase her PCK. Similarly, Teacher T62 described in her interview that the collaboration with teachers through the PD helped her know what the most important chunks of content for students to learn were. Likewise, this teacher talked about how working with other teachers in the PD helped her meet the needs of her minority students:

> …being with other teachers and working with other teachers that were going through the same … you know I got to learn from them how to…cause it was the first year I was here…the minority was African American and just….there's a big difference to Hispanic kids…you have to know how to incorporate different strategies in order to engage them. So I mean talking to them and trying to find out different strategies was really helpful so I really liked it. (T62)

Therefore, the program helped this teacher know different teaching strategies in order to engage the minority population of students she taught, as expressed in the interview; she had also written about this in the reflections two years previously.

Another teacher (T71) in written reflections described that the contact with other teachers who had a desire to improve impacted his teaching as well. Similarly, Teacher T25 responded, " I have learned from other teachers, different techniques to use in class to make learning more attainable or more interesting". Another teacher (T35) also had a related response: "By bringing together teachers from all experience levels from different schools it provides one with different perspectives and resources". In sum, collaboration aided the teachers in finding new teaching methods, adding to their PCK through the PD.

Content and active learning pedagogy.

There was evidence in interviews that teachers had gains in content knowledge or PCK and this aided them in facilitating active learning pedagogy in their classrooms. Some teachers (T27, T62, T68) discussed how the PD helped them understand the standards better so they could implement activities in their classroom. As one teacher explained:

> …it really helped me getting to know those standards 'cause we worked a lot on different things we came up with. Games and things like that for the students based on the standards. So I got a much better grasp of even the structure and then

> learning those standards and learning the TEKS or whatever during the [PD]. (T68)

This teacher was better equipped to create a student-centered environment because of her new knowledge of the standards. Similarly, Teacher T27 created hands-on opportunities for her students, based on the PD's emphasis on state standards (TEKS):

> I use a lot of manipulatives, hands on; and I studied the TEKS. That's one of the things we would do is study the TEKS and how to present, how to demonstrate…I was able to break down each one of those TEKS and pull in an activity. That is so important so that they could remember, that they could reflect back on any time they need it…" (T27)

This teacher's PCK was enriched and this allowed her to create opportunities for her students to explore. (As described previously, she discussed having workshops for her students with manipulatives and whiteboards.)

Teachers grew in PCK, according to responses in the interviews, in other ways and this affected how they provided opportunities for their students to actively engage in content. For example, Teacher T71 talked about how the PD helped her see possibilities of using different forms of technology to engage students and aid in their learning. This teacher had her students actively participate through texting in answers. Another teacher used the interconnections of mathematics and other disciplines like science to provide activities:

> …we did some projects…some activities with the physics class because they were doing something to do with friction and they created a model of the roller coaster and the car and they were looking at the forces that were involved and how the car can go around the loop without falling…but for us as math students we looked at it more as how would be the slant…if you decrease the height or what if you increased the height and that relates to their slope concept (T19).

This teacher also described connecting his new PCK with student activity in the Bungee jumping activity through understanding the 'why' behind what the students were doing, as described previously. He explained that the PD helped him have confidence to do activities such as these:

> …gave me the confidence. Okay I got the content part covered now I want to see how it works when I do the activity. If I don't know the concept myself very well, I don't want to do an activity and see myself fail or make so many mistakes that people just not come out or be a good result at the end so the depth of the knowledge which I received from here would help me design the activity in a more deeper level that kids can see the connection. (T19)

Similar evidence is seen in written reflections from Teacher T27, who described a better understanding of fundamental concepts and how this enabled her to facilitate active learning for students: "The greater understanding of core related topics were in the form of experiments such as the Bungee activity or the Ferris wheel." Teachers' new

knowledge of content or PCK increased their ability to provide learning opportunities for students that promoted the active acquisition of knowledge in mathematics. As Teacher T62 stated in her interview: "They have to learn by actually doing it…"

Content and leadership.

For some teachers (T19, T27, T40, T51, T68, T71) the PD facilitated attributes of leadership due to their newfound content knowledge and PCK. This was demonstrated in excerpts from both interviews and written reflections. One of these teachers, as seen in a written reflection revealed a drive to mentor other teachers with his new knowledge:

> …[I] was able to learn and implement that knowledge within my classroom. Over the time I became a mentor teacher, and the trainer to train other teachers about the valuable resources and the opportunities provided to me by the [PD] program. (T19)

The knowledge gained from the PD enabled this teacher to mentor others. The rest of the teachers who gave evidence of content and leadership working together, indicated that their new knowledge gave them confidence in mind-set, becoming more professional in teaching, previously defined as leadership as a stance (Darling-Hammond et al., 1995). Teacher T68 showed this in both her interview and written reflections. She wrote in a reflection: "…the greatest impact has been in my level of confidence in planning and delivering lessons". This was further expanded in her interview: "…confidence to try more things…I don't have a math background... it goes back to the confidence…because

I had a better understanding in general of where the students were and where they were going" (T68). This indicates that a better understanding of students and the sequence of learning the content created confidence in her teaching.

Collaboration and active learning pedagogy.

Many teachers (T71, T19, T62, T68, T33, T27) interviewed also discussed how active learning pedagogy and collaboration were fostered together in their PD experience. The teachers discussed sharing strategies and activities and how this helped them in their practice. For example, one teacher explained:

> …having that support from [the PD], knowing that I have people to talk to and I have the contacts to call if I need anybody or if I need help. It just takes a lot of pressure like in my case off of my shoulders so I had more confidence and to be able to try new things, which I would have thought, "Well I don't know if I should do that or not…I've never seen people doing this" and so forth. That was a big encouragement…. I have somebody to…or maybe ask somebody to ask to try that activity first in their class and then go for it. So I think that helped a lot along the way…just kind of build that confidence and more of an open mindedness to try new things (T19)

This teacher utilized the collaboration in the PD to support his enactment of new activities in class. It was evident in his observation two years after the PD that activities in his classroom have students actively constructing knowledge. Another teacher talked

about how students would experiment with multiple approaches and strategies to solve problems and then choose which worked best, "um yeah collaboration gave me the freedom to understand, to see different ways, to see different strategies to help the students as they were struggling" (T68). One teacher (T33) talked about the sharing of lessons and activities through the collaboration at the PD, like the tennis ball dipped in paint to create a parabola described previously, where students were finding vertices and equations of different parabolas created. Another example can be seen in this teacher's interview explaining a reason her scores increased because of the PD:

> …I think its because of the sharing piece where we were able to obtain different ideas and perspectives on activities as they pertain to many of the state TEKS and um so it…in the program the greatest part of it was hands on, which our children need quite a bit for better understanding and so I was able to take all of that and bring it into my classroom and use it…(T27)

This teacher believed that through collaboration she learned forms of active learning pedagogy.

Similar evidence was found in the written reflections. Teacher T27 wrote about collaboration and "sharing among teachers…and the great desire to use their talents to teach and impose curiosity on their students…that came together season after season". This teacher felt that she could better create opportunities for exploring mathematics through engaging their curiosity. Another teacher (T68) described how teachers got

together after school to meet with another teacher from the PD to learn "how to program [the interactive whiteboard] so the students could use active expression…". Additionally, Teacher T51 wrote, "Sharing these ideas…encouraged my students to continue to explore and investigate their own math 'challenges'…". Teachers seemed to indicate that collaboration through the PD aided their implementation of active learning pedagogy.

Collaboration and leadership.

In the interviews and written reflections, many teachers (T2, T27, T11, T68, T71, T33, T19) discussed ways the collaboration aided their leadership ability. One teacher (T33) through his interview explained the "interaction with other teachers" helped him gain confidence and therefore aided his leadership ability. Another teacher talked about how confidence gained from the program helped her lead others in her interview:

> …my confidence in being able to share ideas and um and perspectives with other teachers would have increased just because in the [PD] program we depended so much on perspectives from other teachers so kind of changing the perspective that all of your help has to come from above… also it would translate into leadership in your specific school as well. (T71)

Teacher T68 described in her interview how her collaboration in the PD helped her grow in leadership as well: "…I would say the collaboration, yes…because I then networked with other math teachers, kind of came to better understand the networkings, or whatever. It helped me grow as a person so it helped me grow as a leader also…" Another teacher

(T19) in his response through written reflections mentioned, "[The PD] helped me as a teacher to grow, learn and collaborate with other teachers", and in his interview he talked about gaining confidence in his teaching because he had people to talk with. Teachers like these explained that the collaboration found in the PD helped them develop a stance of leadership.

Active learning pedagogy and leadership.

Some teachers (T19, T68) seemed to indicate that the PD influenced and created attributes of leadership that aided their implementation of active learning pedagogy. This was evident in Teacher T68's written reflections when she described having confidence to do the tennis ball activity with her students where they created different parabolas and found the equations and vertices for them, as mentioned earlier. She wrote, "I was confident enough to have my students do an experiment with a tennis ball and food coloring to write quadratic equations." Another teacher (T19), in his interview, also talked about having confidence (indicating leadership as a stance) that he could make connections for students through the activities, such as the tennis ball activity and bungee jumping activity described earlier. This teacher had confidence to create learning experiences for his students where they could actively engage in content through activities. Therefore, there is evidence of active learning pedagogy being influenced by leadership qualities such as confidence in teaching.

RESEARCH QUESTION THREE: DURABILITY OF PD

Interviews and observations provided data to answer Research Question Three regarding long-term teacher change due to the influence of the PD, of the teachers were conducted. The semi-structured interviews, conducted two years after the program's completion, consisted of questions very similar to the prompts for the written reflections allowing comparison of responses in order to assess the longevity of change. Additionally, observations were conducted in order to triangulate with self-reports. As discussed in Chapter 3, eleven teachers were interviewed. The data were analyzed using the theoretical framework outlined previously and broken up into the categories of content that consists of both content knowledge and PCK changes, active learning pedagogy, collaboration and leadership.

Content knowledge after the program.

Teachers reported a perceived change in content knowledge and PCK through interviews that were conducted two years after the program's completion. Temporal cues, such as the words 'today', 'now' and indications of continued use of content knowledge, were utilized to analyze the interview data in order to find what content gains from the program years were still in use two years after the program. The teachers specifically discussed content extensions, interconnection of content, and technology, all of which were a continued use of content knowledge and PCK developed in the PD.

Content extensions.

Content knowledge and PCK that teachers acquired during the PD continued to impact their teaching. For example, teacher T27's new understanding of conics that she gained from the program also helped her teach her courses after the program at an advanced level:

> …conics and breaking down each of the different uh shapes and um so then last year when I taught PreCal and Algebra II, that was very good and now that I'm teaching Algebra I, I can teach it at more of an advanced level.

Other teachers (T33, T62) stated that they used what was learned in the PD to understand the ordering of concepts and better enabled them to prepare their students.

One teacher seemed to extend her knowledge and created new PCK after the program. Teacher T27 described in her interview a new way of teaching linear equations that utilized systems of equations so that students had multiple equations to learn about rate of change (for slope) and starting amount or base costs (for y-intercept) based on applications. She explains:

> So what I'm doing is… is rather than start to teach one line and dismantle that one line as to the slope and y-intercept, we are teaching two. So we are teaching systems. That's how we are starting our school year is with systems… But here it is (referencing worksheet)…Verizon and AT&T and it's who you gonna call? In this problem, rather than just graphing one line and coming up with the equation

> and talking about the slope and y-intercept…you know. We are graphing two lines; so we are talking about slope and y-intercept for two different lines and along with that we are working with the point of intersection and identifying what it means but it gives us a richness of more questions to ask as to you know if you working with less than 150 minutes which would be the better company as opposed to more than 150. (T27)

This teacher not only uses knowledge from the program she learned on conics as described earlier but she seeks out other resources and extends her PCK. Furthermore, she led her Algebra I team to use this unit on linear equations based on systems of linear equations. Interconnections and extensions of PCK exhibited in these teachers' responses indicate a continued effect of the PD.

Interconnections in content.

One teacher indicated he still sought out interconnections in content within mathematics and across mathematics and other disciplines. Teacher T19 discussed how after the program he moved and taught in another town. There, his students worked on a project linking Chemistry and Math and then wrote about the project in English class. This teacher further explained:

> I mean, we can only be able to achieve that if we as teachers have experienced that connection. And then we can guide them through. Oh, how about you look at it this way. Um…look at the history for example or some…go to the social

> studies teacher and talk about it and students were like what? We are not even including social studies part but the idea is to get them to the point where they needed to be so um…I think that's the skill I learned from the program itself. How we cannot just stick to the math only but explore other ways to have the students understand…(T19)

Therefore, this teacher continues to use knowledge about the importance of making interconnectedness of content explicit.

Technology.

Several teachers (T33, T30, T27, T62) talked about continued use of the technological knowledge they gained from the program. Teacher T33 discussed that he still uses knowledge of the interactive software like SMART and Promethean in his classroom, as well as applications on the iPad to do similar activities. Another teacher also talked about his use of technology currently:

> In the old days we just used the book and our knowledge and that was it but now it's a lot different now. It's a lot easier, you know… and the technology I'm learning but I'm already at the end of my career. But I'm still trying. I love this board [interactive whiteboard]. I wish we had it like 30 years ago when I started. All we had were chalk boards. (T30)

This teacher continued to use the knowledge from the program years on the use of technology and this also was evident in his description of using a calculator often in

instruction. Teacher T62 discussed that the PD helped prepare her for the use of TI Nspire calculators since her school just started using them after the PD. The program "actually helped us not to be beginner with it" (T62).

Summary.

These responses seem to indicate that content knowledge and PCK increases from the program years, as seen in data from Research Question Two, continue to be used today. Most teachers, eight of the eleven interviewed, presented evidence in interviews that they continue to use and extend the content knowledge from the PD. Teachers furthered the interconnection of content after the program as well. Additionally, teachers continued to utilize knowledge gained regarding technology and its use in the classroom. Of the teachers where evidence was not seen for the continuation of content knowledge from the PD, one no longer teaches, and the other two did not give examples of specific content or PCK in their interviews. One of these two did show evidence of PCK gained in the PD during her observation; she had students use an interactive whiteboard to actively participate in the lesson, which will be described below. Therefore, there is evidence of the longevity of the theoretical framework component of content from the PD. Furthermore, this researchers' own experience in the PD consisted of similar content knowledge and PCK gains regarding topics covered such as conics and technological PCK, which persisted across multiple years.

Content as demonstrated in observations of practice.

Observations conducted two years after the PD provided data regarding the teachers' content knowledge and PCK. Field notes were taken during each observation and examined in order to triangulate with the teachers' self-reports in the interviews and written reflections. The content coverage observed provided evidence of teachers using extensions of content, content connections, as well as PCK on technology.

Content and content extensions.

All teachers (T19, T15, T33, T11, T68, T27, T30, T51, T62) observed demonstrated an understanding of TEKS, important vocabulary, and content knowledge appropriate for the course. For example, one teacher (T62) had a lesson that focused on independent and dependent events in an Algebra II class, providing a foundational opportunity for her students. Another teacher (T51) used a problem to extend to another related concept, that of slope and the concept of parallel lines. Teacher T11 had students writing definitions on whiteboards of the foundational words function, domain and range in their own words, and encouraged pictorial representations and non-examples.

Teachers' extensions of content knowledge gained in the PD was also exhibited in observations. One teacher (T27) chose to embed the study of linear functions in the study of systems of linear equations in Algebra I class so the students would have a double opportunity to talk about the meaning of the slope or rate of change for each of the equations developed and starting amount or y-intercept.

Content connections.

Connections within mathematics and with other disciplines were demonstrated by teachers, as well. One teacher (T33) made explicit links in his lesson on conditional statements to the big picture of logical reasoning in geometry. Another teacher (T19) introduced a new week-long project where the students were to go shopping online to remodel a room with a budget to adhere to, discounts and other specifications, with competition across groups to spend the least amount of money. This teacher led the students in a discussion about why it was important to shop around for items for the remodeling project he assigned, and made connections to the students' own needs and interests for their own rooms. For example, one teacher (T11) talked about how he could use the TI Nspire calculator to take measurements in the field and then go online to communicate with others regarding the measurements and mathematics used, relating the use of physics with the mathematics that he used to do in a previous job. Teacher T62 related independent and dependent events to variable representations and real life events in Algebra, such as the number of dishes needing to be cleaned and the number of people at a party. Another teacher (T30) anticipated common misconceptions regarding transferring quadratic equations from standard to vertex form and brought in background knowledge of the students; the transformation between standard and vertex forms was covered in the context of conics in the PD.

Technology.

Technology was used during classroom observations to provide strategies to simplify and answer questions; an understanding of the mathematical concepts was needed to utilize these strategies as several teachers did (T11, T51, T27, T68). Teacher T30 utilized technology in representing quadratic equations in graphical and tabular form and facilitated a discussion regarding the meaning of no roots, and how no roots impacts switching between vertex and standard form. Teachers (T68, T51, T33) had students using either interactive whiteboards or document cameras to explain their thinking and solve problems in front of the class.

Issues with content.

One teacher's observation revealed a lack in explicit connection to an important conceptual idea through inappropriate communication. This teacher (T15) had students subtracting polynomials in an Algebra I class, but failed to emphasize that negative one was being distributed when the terms inside the parenthesis changed signs. Therefore, some possible student misunderstanding through the teacher's explanation and examples could have occurred.

Summary.

Classroom observations were triangulated with self-report data from interviews and written reflections. Teachers' content knowledge and PCK were consistent with those

self-reported through interviews and written reflections. Appropriate content knowledge was demonstrated as well as content connections and extensions. Teachers used PCK on technology in lessons, as well. One instance of an omission of important mathematical conceptual understanding was observed in one teacher's classroom.

Active learning pedagogy after the program.

Teachers responded to questions in the interview regarding perceived practice changes from the PD. Again, temporal cues were used to look for changes that continue after the program. These changes are either a continuation of student-centered practices from the years of the PD, extensions, or adaptations of student-centered practices; alternatively, no changes might have been indicated.

Continuation of student-centered practices.

Nine of the eleven teachers interviewed provided evidence of continued practices in line with student-centered learning with one teacher describing his classroom as "very *non*traditional" (T11, emphasis his). Teacher T51 described his practice: "Now my approach is let the kids work problem, let 'em investigate…". Similarly other teachers (T51, T33) indicated that they continue to let students work problems out and share work by using document cameras or interactive whiteboards. For example, Teacher T51 talked about how "the document camera just opened up the students' responses…students can come teach", exhibiting a change in culture from teacher talking to student talking in the

classroom. When asked if she continued to explore new teaching methods, Teacher T27 talked about how she still used activities with her students that she learned from the PD: "I would take my [PD] activities - you know, everything that we did - and I would try to incorporated those and tweak and shift and change the curriculum". Teacher T62 discussed the way she still incorporated an interactive journal where the students interact with the mathematics they are working on daily.

Another teacher (T30) described how he utilized the graphing calculator to have students explore why some quadratic functions have no roots. When asked about how the PD affected the way he thinks about teaching and the way students learned he explained: "…now I'm looking at more visual and less oral…that way they can see it. That's why I incorporate the calculator a lot. That way they can see how it's interrelated, the graphing with the mechanics." (T30) When asked if he continued this change in his teaching, he replied:

> Yep. Like today, what we are doing today…what we are doing is we're looking for vertex given a quadratic in standard or in vertex form and how to find the x and y-intercepts and when we come up with an answer that ends up with a negative under square root, I show 'em by using the calculator why it happens because it doesn't cross the x-axis. You see and that way they can visual see what's going on and why they end up with an error. Or why they end up with a

negative under the square root…see I show ‘em with the traditional way plus the shortcuts and then I end up with the calculator as a visual tool. (T30)

Even though this teacher used the phrase “show ‘em” he actually encouraged the students explore using the calculator and then brought the class together to talk about what they discovered about the graphs of quadratic functions.

Teachers T11 and T2 reported that they still utilized groups in order to facilitate student collaboration. As Teacher T2 put it: “…they work together…talk things out…". Projects were another continued practice to promote active learning for students by several teachers (T2, T19, T27, T62). For example, Teacher T19 said: “…Yeah, now these days it’s more important than ever. Everyone is about…project-based learning and hands-on and so forth.” Therefore, teachers seemed to indicate a continued student-centered approach in their practice.

Extensions or adaptations of student-centered practices.

Several teachers (T11, T19, T27, T62, T68) indicated through their interviews that they have expanded their active learning pedagogy throughout the years since the program ended. Teacher T68, for example, talked about putting students into groups but with another emphasis, “…team building…based around some math problem…more open ended, maybe not one answer where they are having to reason and explain their reasoning and so doing that really built…a culture in my classroom…”

Teachers also talked about student projects (T27, T19, T62). Teacher T62 mentioned she likes to implement experiments in her classroom: "Like at the end of the year we are going to do a project that deals with Excel sheets, looking at stocks and bonds, looking at stocks in the different corporations, then comparing it, looking at the graphs…" Another teacher similarly talked about projects in collaboration with English, History, and Chemistry classes. In this project the students had to create a link between a Math concept and Chemistry concept and write about it, while investigating the history of the concept. Teacher T27 explained in her interview about a project in her class where students were discovering, through the study of systems of equations, which cellphone provider had the best deal for different amounts of minutes used, as described earlier. This teacher used a project to facilitate student-based learning regarding linear equations.

One teacher explained how engaging students in creating posters on vocabulary words helps them learn and explore important math concepts (T11):

> …math is a foreign language to them…I went to the foreign language teachers and learned about how important it is to have the word and the picture associated with that word and maybe an example, and maybe a counterexample……I was known as the powder puff math class…because we did posters once a week…and then one day the scores came in and we were 15 points higher than all my other classes …you target the vocabulary and give them, meaningful ways of exploring the vocabulary and it's a foreign language…those foreign language strategies

helped a lot…but it was one of those moments…let's try it… let's see what happens…(T11).

This teacher extended knowledge by incorporating student-centered strategies from colleagues in other disciplines. A continuation or extension of student-centered practices of many teachers seemed to continue after the PD.

No changes indicated.

There were two teachers (T71, T15) who did not indicate a continuation of active learning as evidenced from interviews. One of these no longer teaches. The other, Teacher T15, struggled to remember changes from the PD in his practice, as described previously, and felt bound by the curriculum imposed on him by his school.

Active learning pedagogy as demonstrated in observations of practice.

Observations of the teachers two years after the PD's completion revealed all observed teachers facilitating some form of active learning pedagogy. Student-centered forms of learning were revealed through students generating ideas and conjectures, encouraging student participation, group work, activities, and projects.

Students generating ideas.

Some teachers worked to encourage students to generate ideas, such as Teacher T11 who solicited student input and conjectures regularly in a discussion utilizing a

calculator to solve problem. The students entered equations in order to compare the table for each answer choice in a problem, discussing reasons for those that did not match. Another teacher (T68) demonstrated quite a few examples where student ideas were solicited, such as when she encouraged students to share multiple ways of simplifying radicals. This teacher engaged many students' input during the discussion of assessment questions. She seamlessly incorporated a Promethean board, calculators both in students' hands and on the interactive board to further student engagement and learning. Multiple students were encouraged to come to the interactive board and explain methods for solving problems throughout the class discussion. One time a student was asked to share because his way of working the problem was graphical rather than algebraic; in this way, multiple representations were encouraged (teaching with multiple representations is congruent with this teacher's self-reported changes). This teacher worked to create an environment where all students were comfortable in sharing and participating.

Teacher T33 facilitated an environment that encouraged student participation and learning throughout the class. This teacher had all students read out loud together and called on students and assigned leaders of groups by the rolling of dice. A few times in the lesson, students investigated and conjectured what was different about statements in order to discover what happens with inverse and contrapositive statements. Teacher T19's students were engaged in their own tasks working out problems involving

measurement and graphs on laptops. During an activity on domain and range, one teacher (T15) solicited student thinking various times.

Teacher T51 occasionally fostered student ideas and questions, for example when students were encouraged to make conjectures regarding the slopes of parallel lines. Another teacher (T30) utilized technology to visually show students different representations of quadratics including algebraic, graphic, and tabular, both on paper and with the calculator software; soliciting more student participation with this lesson would have enhanced it. Although the students were encouraged to graph the functions on the calculator to see what happened with the graph, this lesson would have exhibited more active learning on the part of the students if one or more of the students had been asked to come to the interactive whiteboard and show what they discovered. Teacher T27's lesson also could have had more student-centered learning. This class utilized calculators for a scavenger hunt activity and a document camera for answering student questions and a discussion about assigning variables and writing systems of equations. Having students share more and perhaps bring up and discuss their work using the document camera could have facilitated more active learning opportunities for students.

Groups.

Some teachers had students working in groups, such as the lesson observed for Teacher T33 when his students were grouped to work on a set of problems, with one member of the group assigned to write their responses on the board. The group work had

the students working together to identify parts and types of conditional statements and then the groups reported out on the boards around the room. Groups actively discussed and worked together. Another teacher (T15) had students paired while they worked on an assignment and the groups were usually productive, helping one another, with a few unproductive groups at times. Another teacher (T62) had students working in groups where students were engaged in quality conversation regarding dependent and independent events, but some of the groups were unproductive, not engaged with the task or helping one another. This teacher had students cutting and pasting an assignment where they were to color code independent and dependent events.

Activities.

Teacher T11 had his students actively engaged in a whiteboard activity as well as an activity on the calculators. The progression of the lesson worked well to foster students' success, as the teacher began by having the students brainstorm out loud with him about the previous day's lesson, and then having students write on whiteboards their own definition of the four vocabulary words. Then the teacher had the students' transition to the calculator activity, making predictions and working with linear equations, tables and graphs. Each part of the lesson worked to cognitively engage the students. Another teacher (T27), in part of the lesson, had students working through a scavenger hunt activity on the calculator as a way to bring familiarity to the use of the new calculator, TI-Nspire.

Projects.

One teacher (T19) introduced a project where students would utilize percentages, ratios, and solved equations to select products for remodeling a house. The students were to go on a shopping spree to redecorate six rooms of a house with a specific amount of money that could be spent, specific kinds of objects for each room, and specific stores to shop online. They had to create a spreadsheet with prices, discounts, sales tax, etc. Also, they had to create a poster with pictures of the items and appropriate prices listed. This was a multi-week project. Another teacher's (T27) lesson had students involved in a piece of a larger project, where they were to identify the best cellphone plan as described earlier.

Summary.

All teachers observed had some elements of active learning pedagogy. Teachers encouraged student participation in making conjectures and generating ideas, group work, and engaged students in activities and projects, which was consistent with teachers' self-reported data. Some teachers used technology to facilitate student-centered learning as well. Some forms of active learning pedagogy were not as developed as others, unfortunately. A few teachers' observations showed group work that could have been better facilitated and missed opportunities to incorporate more student ideas and participation.

Collaboration.

Data from the interviews indicated that collaboration continues after the PD. There were two themes that developed from the interviews regarding collaboration after the program, recommended collaboration and seeking collaboration.

A few teachers (T15, T33, T30, T51) collaborate simply because the school wants them to, for example Teacher T15 and Teacher T30. Teacher T15 collaborates with his Algebra I team because it is recommended that they do the same assignments. This indicates a change after the PD as this teacher stated that he did not utilize collaboration during the PD. Teacher T30 discussed vertical and horizontal planning meetings at his school, indicating collaboration mainly during meetings required by the school.

Quite a few other teachers (T2, T27, T11, T62, T19, T68) seek collaboration within their school and are continuing to seek out collaboration with the teachers from the program that teach at other schools, or even with other non-PD teachers. One teacher described the group formed by this PD as a "circle of fellow teachers" (T19). Another teacher (T11) mentioned that he met with a core of the teachers even today, two years after the programs' completion. They meet for breakfast once a month to discuss ideas for teaching, and more often by email or other forms of communication. Another teacher (T68) mentioned in her interview that the collaboration continues with teachers who participated in this PD. Teacher T62 agrees: "…'cause it became, after the program, we still talk; you know, we still talk. They still, "hey have you done this, this and this",

and….so they help me out in certain aspects." Another teacher (T2) still sought out sharing resources with other teachers both electronically and in person.

Some teachers (T19, T11) seek collaboration with teachers from other disciplines such as engineering and the language department in order to better their teaching and find resources to reach more of their students. Teacher T19, while working in another city, became a part of another collaboration and explained: "I was going to her trainings on science because I knew these are the same techniques that I would use in the math class. It's about how you can teach a science concept in an effective way". This same teacher also sought out and worked to keep contact with colleagues. He described:

> …so it is very important to have contacts and colleagues …because you can go to [someone] and find the answer to [your needs]…[This is] some value I got from this program, which I'm practicing still today. (T19)

This teacher gained the value of collaboration through the PD program and continues to seek out and foster relationships with others to further his practice. Collaboration seems to be a lifestyle for many of the teachers from this PD.

Teachers continued to collaborate through various forms of communication such as required meetings, email, or breakfast meetings. Benefits to collaborating from the data of the PD years seems to be implied in the reasons for seeking collaboration such as sharing resources and finding new ways to impact students, that is, improving their practice. Problems with collaboration are not present in data after the PD; however,

problems are perhaps a reason for not seeking out collaboration or implied as no data for Research Question Three.

Leadership.

Teachers exhibited characteristics of leadership after participating in the PD or were furthered in leadership qualities. Teachers demonstrated leadership through a sense of growth or confidence and through positions of influence.

Teacher growth.

Some teachers (T19, T11, T71, T68, T33, T27) seemed to grow and mature as a result of their PD experience. One teacher (T27) talked about how she wanted to change the campus where she worked, so that the teachers would collaborate and share ideas more frequently. Another teacher (T68) felt propelled to continue with her education and emulate the instructors of the program at the university, implementing "culturally relevant teaching specifically for math". Teachers (T19, T11, T2) discussed how they have continued to seek out other PD in order to facilitate more growth in their practices. One, who was a new teacher at the beginning of the PD, describes his efforts to learn more:

> I think one thing is that it created a kind of need for me to keep getting myself to be better. If I would not be in that program I would just going along with what the school had to offer me …But having those year after year, those trainings, and

> meetings and seeing the benefits of it, I would not stop. I would just … remain within that circle of fellow teachers from different places so that I can make myself, make myself better and that training came from that PD itself and that was a good thing. (T19)

Several other teachers (T2, T11, T68, T51, T19) have also chosen to become involved in more PD and are currently taking part this academic year in a STEM program for teachers. Some of the teachers seemed to exhibit a sense of growth, which enables them show leadership.

Additionally, several teachers (T19, T11, T62, T68, T27) mentioned that their teaching had grown because of participation in the PD. Teachers (T68, T19, T71) repeatedly reported that they felt like now they had confidence to try new activities and approaches in their classrooms. By trying new strategies, teachers inevitably become leaders at their campus. One teacher (T62) explained her growth in this way: "I mean, you learn things as a teacher just by trial and error…but having a program to help you develop those skills…I think that's what [the PD] helped me with…developing those skills to better help our students." Teachers used language such as "matured as a teacher" (T27), "open-minded" (T19), and Teacher T68 described her teaching as "definite growth" and "very much a progression".

In sum, many teachers from this PD seemed to indicate growth in their teaching. As mentioned previously, one teacher described an instance of exploratory growth in

teaching where he was not satisfied because he still was missing some of his student population and decided to question the foreign language teachers and came up with the idea of his students creating posters where they come up with examples and counterexamples, providing students with "meaningful ways of exploring the vocabulary"(T11). This is one of several instances from the interview where this teacher continues to search for more ways to reach his students and displays the evolution of his practice as well as a constant striving for improvement. Teachers seemed to continue to grow more confident in their teaching ability after the years of the PD. This shows a mind-set for improving and becoming a more professional teacher, which is part of leadership as a stance as described by Darling-Hammond and colleagues (1995).

Positions of influence.

Teachers who attended this PD assumed roles of leadership in various ways. Some teachers came into this PD in leadership roles already and some acquired positions later. Some teachers were mentors for others and led teams of teachers or presented at conferences.

There were two teachers (T68, T15) who became department chair after the program's completion. One teacher (T11) described himself as a leader by title before the PD but says he is now a leader by reputation. Another teacher (T68), who became department chair this year, talked about how before the PD she "didn't feel experienced

enough" and that the program helped her "grow as a person…grow as a leader also". Teacher T71 stated,

> …my confidence in being able to share ideas and um and perspectives with other teachers would have increased just because in the [PD] program we depended so much on perspectives from other teachers, so kind of changing the perspective that all of your help has to come from above… also it would translate into leadership in your specific school as well.

So this teacher felt like she could lead others because of confidence she gained through the PD. Teachers (T19, T11, T27, T15, T71) additionally discussed ways in which they would go to additional trainings since the end of the PD, and then come back and share with teachers at their schools.

Teachers (T71, T27, T51) talked about how they now mentored other teachers and were able to share more with other teachers because of their experience in the PD. Some teachers (T27, T30, T11, T2, T19) presented at local conferences within their districts or statewide conferences. Some of the teachers (T19, T33) mentioned that they did not feel like much of a leader, however. As described in previous sections, however, Teacher T19 displays leadership in a push for improvement and growth in his practice. In summary, comparing the data from Research Question Two, the program seemed to further the leadership of some of the participants and for a few became the catalyst for even more growth in positions of influence.

Framework integration.

The interview data included some examples where, after the program years, some of the elements of the theoretical framework were working together to enhance teacher change and development. A discussion follows of how each of the framework components, content, active learning pedagogy, collaboration and leadership continue to work together as found in evidence from interviews.

Content and collaboration.

There were four teachers (T68, T62, T19, T2) that described how their PCK was influenced by collaboration after the PD. For example, Teacher T62 explained that she talks about strategies after the program with the teachers from the program, as mentioned earlier. Similarly, Teacher T2 and Teacher T19 described that they continue to share lessons with other teachers through collaboration with them.

Content and active learning pedagogy.

There was no evidence from the interviews that indicated there was a long-term influence of content knowledge and active learning pedagogy influencing one another. However, it was evident in teachers' (T11, T68, T33, T30, T27) observations that several utilized PCK on technology in their classrooms to facilitate active learning for students; for example, Teacher T68 had students utilizing the interactive whiteboard as described previously.

Content and leadership.

Two teachers (T11, T27) seemed to indicate an influence of teachers' content knowledge on their leadership or vice versa, as a long lasting effect of the PD. Teacher T27 used an extension of her PCK gained during the PD to design a unit utilizing systems of equations to teach linear equations (mentioned previously) and then used her leadership ability and influence to lead her team through this unit. Another teacher (T11) described how he went from being reactive in dealing with students' struggles in mathematics to creating a pre-teach model instead and designed an intervention class that he oversees and teaches at his school. He explains:

> We targeted 120 at risk kids and we put them in my classroom. I get the one period a day. That's addition to their math class. They go to the regular teachers for regular instruction for the team. I do a preteach for 15-20 min, targeted on specific TEKS, I know that we can…'cause I look at all their data, but I'm looking at what's coming up… I know they are going to struggle with this and it's a readiness standard so we need to start preteaching it now. And what we immediately saw that first year was instead of being around 70% -72%, 85% and we have been 83-85% success rate on that test we did the preteach model. Because they are going in those classrooms and the direct instruction is making more sense to them. They are able to participate in the class, they are able to get more out of the lesson… (T11)

This teacher led and designed a new intervention program at his school using his developed PCK regarding the TEKS.

Collaboration and active learning pedagogy.

One teacher (T19) revealed a continued influence of collaboration on active learning pedagogy. This teacher collaborated with teachers from other disciplines at his school to create a project where students had to write about a math concept and chemistry concept including their history, as described previously. He said, "I think that's a skill I learned from the [PD] itself, how we cannot just stick to the math only but explore other ways for the students to understand." The PD influenced and taught this teacher the importance of collaboration on facilitating learning experiences for students and he continued to pursue collaborate on active learning pedagogy after the PD years.

Collaboration and leadership.

Some teachers (T2, T11, T19, T68) talked about the way that collaboration fostered their leadership with this continuing today. For example, one teacher discussed how he still collaborates with the same people and how this enables growth:

> …now you look back after the years and the progress we have made, and everything that we did…and we still continue to do because we still collaborate with the same people. It was a life-changing…it was a career-changing event and just to sign on the line and get a part of the program and it's still affecting

> classrooms. But…and we have all moved so not only the classrooms where we started but classrooms in other places. (T11)

This teacher believes that collaboration still enables the teachers to grow and lead others at the different campuses they are assigned now. Another teacher described how collaboration helped him have even more desire for growth in his teaching:

> …But having those year after year, those trainings, and meetings and seeing the benefits of it, I would not stop. I would just … remain within that circle of fellow teachers from different places so that I can make myself, make myself better…(T19)

The collaboration still seems to foster a drive for more as exhibited in this teacher's response.

Active learning pedagogy and leadership.

Several teachers (T68, T11, T19) presented evidence that leadership continued to influence them to create active learning opportunities for their students. Both Teacher T11 and T19 demonstrated an attitude of wanting to improve and create more opportunities for students to actively construct their knowledge through projects and collaborative learning, such as the vocabulary posters (T11) and projects integrating disciplinary knowledge (T19) described previously. Teacher T68 talked about creating a culture in her class of team building (explained previously), and described this form of active learning created for her students as a part of her growth. She stated: "…it's very

much a progression…that we've come through." This indicated that she realized that her teaching and facilitating student-based learning for her students was a progression and a part of how she grew into a more professional teacher.

Summary.

Many teachers continued to have interactions between content knowledge, active learning pedagogy, collaboration and leadership, as evidenced through interviews. The components of the theoretical framework of effective PD continue to influence each other in the long-term.

The final chapter will summarize and discuss the results of this dissertation and work to connect this effort to other research. Conclusions and recommendations will follow the discussion of results.

Chapter Five: *Conclusions and Implications*

The purpose of this dissertation was to investigate the effects and longevity of PD on secondary mathematics teachers' knowledge and practice and their students' achievement. Specifically the dissertation study was guided by the following research questions:

1. How did student achievement change, if it all, for two schools where all the Algebra I and Algebra II teachers participated in a PD program with all the characteristics of effectiveness when compared to similarly matched schools with no participation?

2. What changes in teacher knowledge and changes in their perception of practice resulted from participating in this PD program?

3. What long-term changes are evident in teachers' practice from this PD and how do these compare to the changes during the program?

This research was intended to further the field by providing a description of changes in teacher knowledge and practice as a result of PD for high school teachers, while looking for plausible links that could influence student achievement therefore working to establish "links among professional development, teacher learning and practice and student learning" (Yoon et al., 2007, p. 3). This investigation utilized teacher and student data from the program years, as well as data collected two years after the professional

development, providing a unique look at the longevity of effects on the teachers as recommended by Kazemi and Hubbard (2008).

SUMMARY OF RESULTS

Research question one.

Regarding Research Question One, the quantitative analysis revealed an improvement in each of the grades of the PD schools except for 9th grade in one of the schools (See Table 3). In School 1 both 10th and 11th grade increased passing percentage of students dramatically, by 38 percent and 35 percent respectively. School 2 improved in each of the grade levels, with 9th and 10th grade improving by 12 percent and 11th grade increasing their percent meeting state standard by 18 percent. School 1's passage rate for 9th grade did not follow the general trend of improvement, decreasing 2 percent. However, student achievement changes were similar in the PD schools and the matched ones with no-PD. Since the comparison schools did show similar gains in student achievement the increases in School 1 and School 2 may or may not have been due to the teachers' involvement in the PD. In summary, the PD schools did not have greater student achievement gains than the schools with no PD. This result does not support the premise that PD programs based on the theoretical framework adopted in this dissertation would work through teacher practice and knowledge to affect student achievement.

Research question two.

For Research Question Two, the results reveal changes in teacher knowledge and perception of practices from the PD during the years of the PD. These changes were outlined according to the theoretical framework, namely, content (including coherence), active learning pedagogy, collaboration and leadership.

Content.

Content knowledge changes during the years of the PD were demonstrated through teacher self-report in written reflections, interviews, and the "Algebraic Ideas" test, which indicated a statistically significant difference from before the PD to afterwards for this sample of teachers with an effect size of 0.87. In the area of content knowledge teachers reported that they grew in an understanding of the interconnections within mathematics and across disciplines. Included in content was the impact of the PD on the teachers' perceived PCK, which revealed a greater knowledge to support the creation of 21st century classrooms, and in tools for teaching such as technology.

Active learning pedagogy.

In written reflections from the years of the PD, triangulated with segments of the interviews referring to the PD period, teachers reported promoting active learning pedagogy and their reasons for doing so. Teachers named forms of activities that they implemented as a result of the PD, such as hands-on learning, projects, and group work.

Teachers also talked about ways of promoting student accountability in learning, as well as reasons for creating active learning opportunities for students.

Collaboration.

Teachers described in written reflections and in interviews how their collaborations with colleagues were enriched and promoted by PD, both with colleagues from the PD and with others. They discussed forms of communication including how and when they collaborated, and the benefits of collaboration such as new perspectives, resources, and growth. A few teachers also mentioned some obstacles to collaboration, perceiving that some colleagues did not want to collaborate or feeling that collaboration was unnecessary.

Leadership.

Teachers indicated through written reflections and interviews that during the PD they grew in leadership. Some served as informal leaders by mentoring or sharing with other teachers and one utilized his role as department chair to lead the mathematics teachers at his school to implement practices learned in the PD. Teachers also assumed a leadership stance (Darling-Hammond et al., 1995). Their new attitude of leadership was often described through the term "confidence". Many teachers mentioned gaining confidence in their teaching ability or in trying new strategies in the classroom, making them (perhaps inadvertently) instructional leaders at their campus.

Research question three.

Research Question Three set out to investigate the longevity of the PD's effects on teachers' knowledge and practice and also addressed how changes from the years of the PD compared to the changes in teachers after the program. In other words, which of the PD's effects continue to be evident in the teachers' practice or self-reported practice or knowledge? Interviews and observations provided the data for these changes that were organized by the theoretical framework components.

Content.

Data from interviews, triangulated with data from observations two years after the PD, revealed that teachers were still using content knowledge developed during the PD, with some teachers even extending this knowledge. Teachers also continued to demonstrate interconnections within mathematical topics and with other disciplines. They also demonstrated possessing the PCK needed to facilitate learning with technology and communicating the need for mathematics in the real world in contexts such as redecorating a room or in fieldwork as a physicist.

Active learning pedagogy.

After the PD, nine of eleven teachers interviewed indicated that their emphasis on student-centered forms of learning continued. Observations indicated forms of active learning for some portion of the lesson in each of the teachers' classrooms such as

collaborative learning, investigations using calculators, or student utilization of interactive whiteboards.

Collaboration.

After the PD, interviews indicated that many teachers still are seeking collaboration with colleagues from the PD or others, in addition to some teachers even seeking collaboration with teachers outside their discipline. Teachers discussed reasons for pursuing collaboration such as sharing resources, reducing work load, and discussing new ideas for pedagogy. A couple teachers described only collaborating when asked to by their respective schools, for example in their content teams.

Leadership.

In the interviews, teachers talked about how the PD affected their leadership two years after the PD. Some teachers assumed new formal leadership roles after the PD with two becoming department chairs. One teacher who was already department chair at the time of the PD described being a leader now by reputation as well as in the title. After the PD, seven teachers indicated a continued effort for growth in their teaching by seeking more PD or educational activities and/or a continued confidence in the classroom. This demonstrated a continued stance of leadership (Darling-Hammond et al., 1995) where teachers had confidence to be innovators in their own classrooms and influence others around them.

CONCLUSIONS AND DISCUSSION OF RESULTS

This dissertation set out to examine the effect of a PD built on elements of effectiveness for high school mathematics teachers on both the teachers' practice and knowledge and how this effect may have influenced student achievement. Although teachers' practice and knowledge was affected by the PD according to their self-reports in written reflections and interviews, and the "Algebraic Ideas" assessment, this change did not correlate with change in student achievement when compared to other similarly matched control schools. The discussion of these results will be outlined separately by research question.

Research question one.

Previous research tracing PD's effects from teacher change to student learning is sparse, especially for the upper grades (Yoon et al., 2007). The two studies found for high school PD effects on student achievement presented a positive association of PD to student learning (Cole, 2010) and an outperforming of students in control classes by small effect sizes (Greenleaf et al., 2011). Neither of these studies investigated a PD that concentrated mainly on content knowledge as in this dissertation, with one PD on assessment (Cole, 2010) and the other on integrating literacy in Biology (Greenleaf et al., 2011). The Cole (2010) study did not specify elements of effectiveness as outlined in the theoretical framework for this dissertation nor did it describe effects of teacher knowledge or practice changes; however, the Greenleaf et al. (2011) study did utilize a

theoretical framework similar to this dissertation to investigate teacher change. In studies regarding PD for middle school teachers and effects on student achievement, the results were mixed with one study about a PD that emphasized inquiry and content displaying better odds of student success and proficiency in mathematics (McMeeking et al., 2012), and another PD specifically on content of rational number topics showing no significant difference between students whose teachers went through PD and those of control teachers (Garet et al., 2011; Garet et al., 2010).

Some reasons Garet et al. (2010) gave for the null results were that the change in teachers as measured in the study "may not be related to student performance in mathematics" or possibly because the measures of practices were inadequate because they looked at quantity, not quality (p. 67). The study conducted in this dissertation could also have similar reasons for null results. Even though the achievement measure (TAKS test) and PD content were aligned as described in Chapter Three, and teachers significantly grew in content knowledge and exhibited and reported increases in PCK, this change did not translate to increased student performance on the assessment. Additional factors that might have influenced the results include the fact that, only one observation of each teacher was conducted, making it hard to verify the quality of the practices consistently demonstrated by each teacher, and these observations took place two years after the PD. The teachers' quality of practices during the PD was not measured and only self-reported through written reflections and interviews. Even though

the teachers were changed as measured by the data sources in this dissertation, this may not accurately reflect changes that could have affected student achievement.

Another potential factor leading to null results is the time frame of the study. Perhaps it would take more time to demonstrate a significant change in student achievement. Impact takes time; for example, it took 25 years for reform standard-based curriculum to exhibit substantial results (Burkhardt & Schoenfeld, 2003, p. 4). The impact of PD, especially for high school teachers, through teacher change and on to student achievement is perhaps also delayed. The data in this dissertation indicated a continued growth in some teachers two years after the PD, and this time period was not included in the student assessment results. Perhaps with more time, further teacher growth could result in an improvement in student achievement.

The quality of the instrument used to measure student achievement gains is another issue. There is some research that claims that standardized tests, like the TAKS, are not sensitive to instruction. Perhaps, as teachers' practice and knowledge changed, students actually learned better, but this impact was not detected by the assessment (Pham et al., 2009, pp. 180, 186).

The alignment between the content of the PD and the TAKS instrument itself was not perfect. The PD emphasized content mainly from Algebra-related objectives with some coverage of other tested objectives. While the TAKS tests covered Algebra objectives, other topics dealt with eighth grade mathematics or Geometry content. It is

possible that students did better in content covered by the PD but their performance on other objectives that were not included in the PD's content did not improve and is hiding real gains in algebra.

Another issue concerns the test measure used, percent passing rate. Individual student scores were not available for analysis, only the percent of students per grade-level who met the state standards. In other words, it is not apparent how much above passing the student scores were for either the PD schools or comparison schools. The other two studies investigating student achievement for high school PD both utilized student scores (Cole, 2010; Greenleaf et al., 2011). Perhaps actual student scores, when compared to the control schools, might have resulted in statistically significant results.

Additionally, data at the teacher level were not available and teacher variability could be behind the null results. For example, one teacher, who was math department chair during the PD, mentioned that not all the teachers who attended the PD from her school exhibited better practices She explained in her interview:

> …We had one teacher who was showing movies and I just felt so uncomfortable, because she was working with a group of kids who were going to count against our AYP [Adequate Yearly Progress] accountability, our testing here at [School 1] and she was showing movies. I mentioned it to two of the principals. I said,

> ‘It’s not fair that some of us are working hard but our scores are going to be averaged with theirs and when you average our scores in the end we’re going to fall short. (T27)

This teacher described one teacher’s lack of change from the PD and she felt this made their campus (School 1) not perform as well in 9th grade. Additionally, teachers who reported changed practices from the PD did not all grow and change with the same intensity or level of implementation (Knapp & Peterson, 1995; Miller, 2012), according to the data (this will be considered further in discussion of Research Question Three). For example, one teacher (T15) mentioned he felt bounded by a set curriculum and this inhibited his implementing practices learned from the PD. Perhaps a set curriculum for teachers could have limited the effect of the PD on some teachers which could have caused an overall null result. Also, at least half of the teachers at School 1 were not at the school two years before which hinders the interpretation of the results for that school.

Thus, several factors could be behind the null results found in this study. Teachers’ quality of self-reported practices was not well verified in this study. Perhaps more time for teacher development or a more aligned assessment instrument to content focused on in the PD would have caused changes in student achievement to surface. Also, the use of student achievement as measured as a percent passing at each grade level and not separated by teacher could be behind the null results.

Research question two.

This dissertation study built on previous work in PD research that had identified key characteristics of effectiveness, that is, long-term programs that allow teachers to work through content-related tasks, provide coherence with the teachers' practice, utilize active learning, promote collaboration, and foster leadership. It informed the theoretical framework for studying this PD program as discussed previously (see Figure 1), grouping content and coherence together, as the content standards provided coherence for the teachers. The results add to the literature regarding teacher change from PD by describing each of the framework components in greater detail and also how they work together, i.e., framework integration. This discussion will look at each of the components individually and then later will discuss how they appear to influence one another to affect teacher knowledge and practice according to the teachers' data.

Content.

This dissertation found a significant difference between pre and post assessment of teachers' content knowledge and PCK with a large effect size of .87. This growth in knowledge cannot unambiguously be attributed solely to the PD, as teachers could have increased in content knowledge over the years through experience or through other PD opportunities. This study did not have evidence to completely rule out these possibilities. A few of the teachers (T2, T27, T62) mentioned district-led or other PD opportunities although it was not clear exactly when these took place. Teacher T2 talked about how in

general he attends PD every year and Teacher T27 discussed getting together with teachers from her district during in-service training. Teacher T62 mentioned receiving training on bringing reading into her classroom, which should not have affected mathematical knowledge tested here. As there is little reason to suspect increases in content knowledge and PCK due to other sources, it can be cautiously inferred that the PD may have been behind the changes in the test scores. As for the teachers whose scores dropped, Teachers T11 and T62 both had great attitudes when interviewed about content knowledge they had learned from the PD and possibly did not test well on the post test whereas Teacher T15, who went down two points, did not remember content knowledge gained from the PD when asked in his interview.

Content knowledge of the teachers was enhanced in the PD in not only specific topics that they taught but also in terms of connections within their discipline of mathematics. This understanding is akin to what Shulman (1987) described as a part of "scholarship in content disciplines" consisting of "structures of subject matter" and "principles of conceptual organization" (pp. 8-9). Teachers discussed learning of topics other than Algebra, which was the focus of the PD, such as geometry concepts and topics related to Pre-Calculus and Calculus. These were covered through extensions in the PD where pedagogies and strategies from the Algebra content were presented as transferable to other courses in high school mathematics. This allowed teachers to gain a better grasp of the organization of mathematics and the ordering of topics or standards that they teach.

For example, one teacher (T68) explained that she gained a better understanding of the structure of the content standards. This deeper understanding could also be described as what Ball and colleagues (2008) have labeled horizon content knowledge (HCK), the "awareness of how mathematical topics are related over the span of mathematics included in the curriculum" (p. 403). The National Council of Teachers of Mathematics (NCTM) recommends knowledge of big ideas in mathematics and the ability to represent content connections (2000, Chapter 2, The Teaching Principle section). When teachers connect the big ideas in mathematics they can in turn integrate knowledge for students in ways that promote transfer (Loucks-Horsley et al., 2010, p. 56).

Teachers' content knowledge seems to have expanded the single discipline of mathematics to include how the math topics relate to concepts in other disciplines such as the sciences. The teachers from this PD described several examples of integrating math with other subjects like science to create rich, relevant learning experiences for their students; for example, Teacher T11 connected an equation for finding velocity with the slope-intercept form of linear equations. The integration of mathematics and science has many benefits for students including fostering critical thinking, creating relevance, allowing students to make conceptual connections, and encouraging discovery of patterns and relationships (Johnston, Ni Riordain, & Walshe, 2014, p. 16). Additionally, learning mathematics alongside science can help provide multiple contexts, which can promote transfer of learning, as well (Bransford et al., 2000, p. 62).

Teachers discussed ways in which their PCK grew concerning tools for teaching, especially in the area of technology. The PD aided these teachers in the use of calculators and interactive whiteboards to facilitate student engagement. One teacher (T68) stated that the training on both calculators and interactive whiteboards helped her incorporate technology in ways that "greatly enhanced the classroom experience" of her students. This was a very important part of the PD's effect because research regarding PCK on technology has found that there can be many barriers to teachers' use of technology such as a "lack of confidence, lack of competence and resistance to change in integrating technology" (Johnston et al., 2014, p. 16). Previous research had found that PD on the use of technology helps promote confidence for teachers (Bennison & Goos, 2010). Additionally, it is important that training in technology include a pedagogical focus (Johnston et al., 2014) as this PD seemed to provide for these teachers. According to NCTM (2000), "Technology is essential in teaching and learning mathematics" (Chapter 2, Principles for School Mathematics section). According to Bransford et al. (2002), technology can be a tool in scaffolding student learning, help create "a deeper understanding of phenomena in the physical and social worlds" (p. 215) through building and manipulation of models for students, and be used as a way for teachers to more easily give feedback to students. It can also provide a means of assessment (Means, 2006). The data revealed that teachers used technology as a way of assessing student understanding such as Teacher T33 and T68's use of interactive whiteboards. Student learning was

scaffolded through modeling by the use of calculators in several teachers' observations (T30, T11, T51). Additionally, researchers state:

> Technology has motivational benefits as a 'hook' that gets students to participate. It also can help sustain interest and promote cognitive engagement…Interest may stem from the variety of activities technology affords; students can build and represent knowledge in different ways, such as using visualization and multimedia capabilities. Students' feelings of autonomy and cognitive engagement are likely to be increased…
>
> (Blumenfeld, Kempler, & Krajcik, 2006, p. 484)

This use of technology for engagement and motivation was seen in observations of the teachers as well as through teacher self-report in written reflections and interviews. Teachers' PCK regarding the use of technology as developed by the PD helped promote confidence in creating learning environments that gave students opportunities for cognitive engagement and building and demonstrating understanding of mathematics as recommended by research on developing PCK on technology.

In summary, research on teachers' PCK regarding technology recognizes a lack of confidence and resistance of teachers to utilizing technology (Johnston et al., 2014). Results from this dissertation indicate that this PD met this need for teachers' PCK. Teachers' PCK should also include an understanding of the use of technology for modeling, scaffolding, assessment, engagement, visualization, and for building and

representing new knowledge for students in multiple ways (Blumenfeld et al., 2006; Bransford et al., 2000; Means, 2006) and this was seen in teacher data as well.

The PD's effect on content knowledge for teachers seemed to have helped teachers gain an understanding of connections within mathematics, connections with other disciplines, and in the integration of technology. This seems to support Borko's claim that:

> …teachers must have rich and flexible knowledge of the subjects they teach. They must understand the central facts and concepts of the discipline, how these ideas are connected, and processes used to establish new knowledge ... PD programs that include an explicit focus on subject matter can help teachers develop these powerful understandings. (Borko, 2004, p. 5)

In other words, a focus on content in PD for high school mathematics educators helps develop knowledge of the discipline and ways to help teachers promote new knowledge construction for students through the use of integrated teaching with other disciplines or with tools such as technology.

Active learning pedagogy.

Teachers described the use of various activities, hands-on opportunities, games, and group work as forms of student-centered pedagogy, with this change in their practice attributed to influence of the PD. Researchers (Scardamalia & Bereiter, 2006) refer to 'active learning' as a "shift from didactic approach focused on the transmission of

knowledge and skills to…where the focus is on the students' interest-driven activities that are generative of knowledge and competence" (p. 112). Teacher data reveal pedagogy that promoted student accountability and student-initiated learning. Student accountability was demonstrated in students explaining their learning to the class, a common way to promote and structure accountability in students (D. W. Johnson & Johnson, 1999) through the use of technology. One teacher (T40) described his implementation of "student-based activities…[to help] students remember the information over time". This promotion of knowledge retrieval is essential in developing experts rather than novices. As Bransford et al. (2000) explain, expertise entails "methods for retrieving related chunks and procedures for applying these informational units in problem solving" (p. 38). The more students are actively constructing knowledge, the easier the retrieval of that knowledge will be. The active learning pedagogy of teachers that they attributed to the PD provided research-based practices and, as one teacher (T11) phrased it, classrooms that are "very *non*traditional" with "exploratory learning" and "student collaboration".

Another teacher (T19) came to realize that providing experimentation for students to investigate and discover mathematics was not enough. The experience in the PD helped this teacher provide scaffolding throughout the week for students to better understand the purpose behind doing the activity. This coincides with the types of learning experiences for students recommended by Lehrer, Schauble and Petrosino

(2001) when they explain many students do not understand "what the experiment was about" and the necessity for "carefully tuned forms of scaffolding and instruction" (pp. 252-253).

Regarding the teacher data that described a shift to more group work for students, although it is reported as data indicating active learning it is not certain that this was the case and more observations of the teachers would be necessary to verify. Research indicates that some forms of group work are not as effective as others and require special conditions such as shared goals, mutual encouragement from the students involved as well as careful planning and monitoring by the teacher (D. W. Johnson & Johnson, 1999).

Teachers provided multiple reasons for providing active learning opportunities for their students, displaying an understanding of the theory of how learning occurs. Their rationales were in line with the *Principles and Standards for School Mathematics* (NCTM (2000), which states: "Teaching mathematics well involves creating, enriching, maintaining, and adapting instruction to move toward mathematical goals, capture and sustain interest, and engage students in building mathematical understanding." (Chapter 2, The Teaching Principle section) The teachers from this PD seemed to have grown in their pedagogy in this manner.

Collaboration.

Collaboration was a major part of this particular PD, with collaborative being part of the name of the PD program. This focus was reflected in the data from the teachers in

discussion about ways that they collaborated. Teachers from this PD collaborated in person and through technology. Teacher learning is more productive and effective when they collaborate and learn from one another, and working as a community is essential (Fishman & Davis, 2006). The promotion of collaboration among high school teachers is perhaps even more important, as content specialists such as those who teach in upper grades often choose to isolate themselves and are less likely than elementary teachers to engage in collaboration (Wei et al., 2010), running the risk of becoming stagnant in their teaching. This could be seen in one teacher (T15) in particular, who did not seem to seek collaboration and believed it was best for him to do lessons on his own during the PD. Although willing to help other teachers, he did not initiate collaboration.

Researchers (Fishman & Davis, 2006) explain that when groups of teachers collaborate, support occurs for "teachers in the sharing of diverse expertise, in the construction of professional knowledge bases, and in supporting newcomers as they are apprenticed into increasingly expert practice" (p. 539). This was seen in teacher data when teachers gave and received feedback, shared perspectives and resources. Some teachers also discussed being mentored by others in the PD, and some talked about mentoring others.

When teachers collaborate, they can "share successes and failures with pedagogy and curriculum development" (Bransford et al., 2000, p. 197). This was present in the teacher data when they described instances where discussion took place regarding what

worked in their classrooms and what did not, along with ways to better meet student needs. Sharing resources for use in their classrooms was a major theme among responses, with one teacher explaining that having someone else to try out something new in their classroom first and then sharing the outcome was beneficial. Some teachers noted that collaboration helped them deal with common problems relevant to the particular teaching situation they shared. Others talked about how it was beneficial for them to collaborate with people who had different, fresh new experiences. Many of the teachers from this PD created communities where sharing new ideas for pedagogy or curriculum was the norm. This seemed to represent the creation of a community where transformation potential was present due to what Nelson (2009) called collaborative inquiry where teachers "engage dialogically to develop common understandings about learning, students, curriculum, subject matter, teaching practices or contextual influences on these components" (p. 551)

Leadership.

Many teachers who participated in this PD grew in confidence regarding their teaching while some also pursued acts of leadership. The data from this PD coincides with claims from other PD research, to show "a form of teacher leadership is being created that holds the promise of being more than a set of formal, bounded, titled, and assigned roles within…schools" (Darling-Hammond et al., 1995, p. 95). Whereas Darling-Hammond and colleagues were discussing Professional Development Schools, this PD that took place outside of school and where teachers collaboratively engaged in

content-related tasks also fostered leadership. Teachers grew in their leadership mind-set as they experienced the PD and became more confident in their ability. They looked at themselves as a learner within the community of other teachers in the PD. For some teachers this confidence was in their classrooms (T25, T33, T71, T68, T19, T51), but for others the gain in leadership influenced other teachers in their schools (T27, T2, T11). An example of teacher change from PD that exhibited leadership as a stance through the growth of confidence can be seen from one teacher's interview:

> …my confidence in being able to share ideas and um and perspectives with other teachers would have increased just because in the [PD] program we depended so much on perspectives from other teachers so kind of changing the perspective that all of your help has to come from above… also it would translate into leadership in your specific school as well. (T71)

Essentially, this PD seemed to "support teachers to deepen their professional expertise…" (Loucks-Horsley et al., 2010, p. 71) and seemed to be the catalyst for growth in some teachers.

Regarding actual positions of influence, the PD enabled teachers to better fulfill these roles as well. Examples of teacher data include teachers supporting other teachers at their respective schools (T2, T11, T27) and/or sharing expertise at teacher conferences (T51). Some grew in their roles in actual leadership positions, that is, math department chairs (T11, T27). Researchers explain, "Given the critical need in mathematics and

science to retain new teachers and support more experienced teachers, developing teacher leaders…can renew and challenge teachers and contribute to the cultural shift in schools toward learning communities." (Loucks-Horsley et al., 2010, p. 128). The data from this PD indicate many teachers contributing to and promoting change in their schools either through positions of influence or via growth and confidence creating leadership as a stance (Darling-Hammond et al., 1995).

Research question three.

Research Question Three investigated the long-term influence of the PD on teachers' practice and knowledge, an underdeveloped part of PD research according to Kazemi and Hubbard (2008). Previous research has found that support from others was very important in teachers' continued application of PD principles (Antoniou & Kyriakides, 2013; Dresner & Worley, 2006; C. Johnson et al., 2010; Knapp & Peterson, 1995). Also in previous work, teachers seemed to implement practices and knowledge learned in the PD in differing levels of enactment (Knapp & Peterson, 1995; Miller, 2012; Stronkhorst & van den Akker, 2006). The teachers' own personal initiative was also an important part of the longevity of the PD's effects (Erickson et al., 2005; Frederick, 2013; C. Johnson et al., 2010; Miller, 2012). The discussion of results for Research Question Three utilizes a comparison of the theoretical framework components with the objectives of the PD and then continues the discussion of longevity of PD

through the lens of previous research: support from others, personal initiative, and levels of enactment.

Comparison of theoretical framework to PD objectives.

Part of the longevity of a PD is exhibited in whether teacher data after the PD still show objectives of original PD's intent. This long-term PD program targeted improvement in teachers' competence and confidence of the standards of the State selected TEKS both in knowledge of those standards and in pedagogy. The instructional objectives included pedagogy that was standards-based, constructive, explorative, based on technology, and inclusive, and the encouragement of group instruction. Additionally, the PD promoted teacher leadership through collaboration with other teachers. Teacher data from each of the theoretical framework components exhibited evidence of the objectives after the PD, as described below.

Content.

The framework component of content was present in the PD objectives as teachers' increase in understanding of the TEKS in specific topics such as conics, the sequencing of topics, as well as the extension of the knowledge gained in the PD like Teacher T27's new linear equations unit based on systems and Teacher T19's project on integrating multiple disciplines, using and extending PCK. Teachers discussed still using technological PCK in their use of tools such as interactive whiteboards and calculators; in

the observations this was exhibited as well. All the contacted teachers, either in interviews and/or observations, revealed evidence of use of PCK from the PD two years after the program's completion. Teachers' knowledge base seemed to have benefited from the PD in PCK, described by Shulman (1987) as "the intersection of content and pedagogy, in the capacity of a teacher to transform the content knowledge he or she possesses into forms that are pedagogically powerful and yet adaptive to the variation in ability and background presented by the students" (p. 15).

Active learning pedagogy.

The framework component of active learning pedagogy was consistent with PD objectives as well, specifically inclusive instructional strategies, group instruction, students' construction of knowledge, exploration, and students making sense of mathematics through instruction that is standards-based. Such practices "encourage students to participate in processes that include conceptual inquiry and the use of skill in solving meaningful problems as a part of authentic projects" (Greeno, 2006, p. 92). Additionally, "authenticity, inquiry, collaboration, and technology engage learners so that they will think deeply about the content and construct an understanding that entails integration and application of the key ideas of the discipline" (Blumenfeld et al., 2006, p. 475)

In their interviews, nine of the eleven teachers discussed providing students with opportunities to explore concepts in mathematics through various activities, facilitating

group work, letting students' voice their understanding, leading student investigations through the use of graphing calculators, and implementing project-based instruction. Teaching strategies like the vocabulary posters (T11) and team building group work (T68) provided learning access for multiple students. The two teachers who did not indicate through interviews a use of active learning pedagogy were Teacher T15, who presented some pair sharing (an inclusive strategy) in his observation and Teacher T71, who no longer teachers and was not observed.

Teachers seemed to still be using some instructional strategies that support student construction of knowledge two years after the PD. With these strategies, students are apprenticed into a culture that creates knowledge and "involves students not only [in] developing knowledge-building competencies but also [having] them come to see themselves and their work as part of the civilization-wide effort to advance knowledge frontiers" (Scardamalia & Bereiter, 2006, pp. 97-98).

Collaboration.

The PD emphasized teacher learning through collaboration, aligning with the theoretical framework. Collaboration is an important part of teacher learning: "community is essential to effective teacher learning" (Fishman & Davis, 2006, p. 539). Six teachers continued to seek out collaboration with others from the PD or others, tow years after the PD. Teachers gave indications that there was a strong bond of learning together by using description such as "circle of fellow teachers" (T19) and "core of

people" (T11). The majority of teachers continue to utilize collaboration to better their knowledge and practice, displaying a continued effect of the PD.

The interview data indicated that four teachers seemed to collaborate only when required to do so by their schools, which is common for high school teachers (Wei et al., 2010). One teacher (T15) changed from not seeking collaboration during the PD to collaborating with his content team at his school after the PD.

Leadership.

The PD aimed to grow leadership in teachers, consistent with the theoretical framework. Teachers exhibited leadership when they took on formal leadership roles such as department chair (T68, T15) or became trainers of others (T19, T11, T27, T15, T71). Leadership as a stance was seen in growth and confidence in teaching (T19, T11, T71, T68, T33, T27), and created an ambition for more PD or education to further their growth in teaching ability (T68, T11, T2, T19, T51). This PD, of which this researcher took part in previous years, also created this type of leadership, creating a motivation for more PD and education and building confidence in teaching. Darling-Hammond and colleagues (1995) explain developing leadership in PD as a stance this way:

> Rather than officially assigning teacher leaders to predesigned functions, a process that requires the teacher to fit the designated leadership mold…offer the possibility of the school's taking shape around its team as the teachers contribute

their individual interests, abilities, and experience to the community of learners and leaders. (p. 95)

Teachers described their growth from the PD with phrases such as "matured as a teacher" (T27), "it created a kind of need for me to keep getting myself better" (T19), "definite growth" and "very much a progression" (T68). Some teachers revealed growth in an initiative to lead others either by position or by mentoring and training others. Teacher T11 described his change from being department chair by title only to now being a leader by reputation, for example. All of the teachers interviewed, except Teacher T30 (who mentioned his retirement this year), talked about a growth in either confidence or maturity in teaching and/or leading others through positions of influence two years after the PD. Research indicates that "teachers continue to expand their knowledge base, and begin to strengthen their dispositions toward self-improvement…taking on leadership roles in their schools" (Fishman & Davis, 2006, p. 536)

Summary.

Each of the components of the theoretical framework was present in the objectives of the PD, and evidence for the effect of each component was found in almost all of the teachers two years after the PD, showing longevity of the PD effects. Teacher data showed teachers still utilizing knowledge gained from the PD regarding the TEKS and instructional strategies emphasized that is inclusive, constructive, standards-based, and explorative; group instruction; and use of technology. This sample of teachers

exhibited the sustainability of this PD's effect two years after the conclusion of the PD program.

Support from others.

The data from this group of teachers demonstrated that support from others was an important part of the longevity of PD's effects. After the program years many teachers (T2, T27, T11, T62, T19, T68) still seek out collaboration with those who attended the PD or others. Regarding content or PCK from the PD, some (T62, T27, T19) of those who continued to seek collaboration also stated they utilized or extended PCK from the program.

Four teachers (T2, T11, T19, T68) discussed ways that collaboration after the PD fostered leadership or spurred their growth in teaching. The support of collaboration with other teachers promoted and furthered teachers' leadership as a stance (Darling-Hammond et al., 1995).

Teacher T15 and Teacher T30 stated that they did not seek collaboration, only doing so when required by their school. Teacher T15 did not indicate during his interview a continuation of the use of active learning pedagogy. Teacher T15 did show some evidence of having students work in pairs through problems in his observation; however, the teacher did not provide enough support or encouragement for the pairing of students to support the active learning of students. Teacher 30 did use some forms of student-centered learning as indicated by his observation and interview when he had students

explore quadratics and their roots in the calculator. However, this was a small portion of his class, most of which was lecture-based. Although some student-centered pedagogy was revealed in Teachers T15 and T30, it was not a major part of the learning environment as it was for several other teachers (T11, T19, T68) who still collaborated. Collaboration seemed to facilitate teachers' ability to continue to create learning experiences that were congruent to PD supported practices of active learning.

Personal initiative.

Previous research indicates that teachers' personal initiative to refine practices and foster growth in their teaching as well as further their careers is an important part of the longevity of PD effects. Personal initiative is aligned with the definition of leadership as a stance as described by Darling-Hammond et al. (1995), "a stance, a mind-set, a way of being, acting, and thinking as a learner within a community of learners, and as a professional teacher" (p. 95). Teachers T27 and T11 demonstrated a personal initiative to better their practice by creating new ways of reaching students and impacting student learning, through Teacher T27's study of linear equations through systems and Teacher T11's pre-teach model and development of intervention class as well as his idea to utilize the creation of posters to study math vocabulary. Teachers T19 and T68 also talked about an initiative to design student-centered pedagogy where projects that integrated multiple disciplines were enacted (T19) and culture of team building created in Teacher T68's classroom. Teachers who had the initiative to grow in their teaching and seek

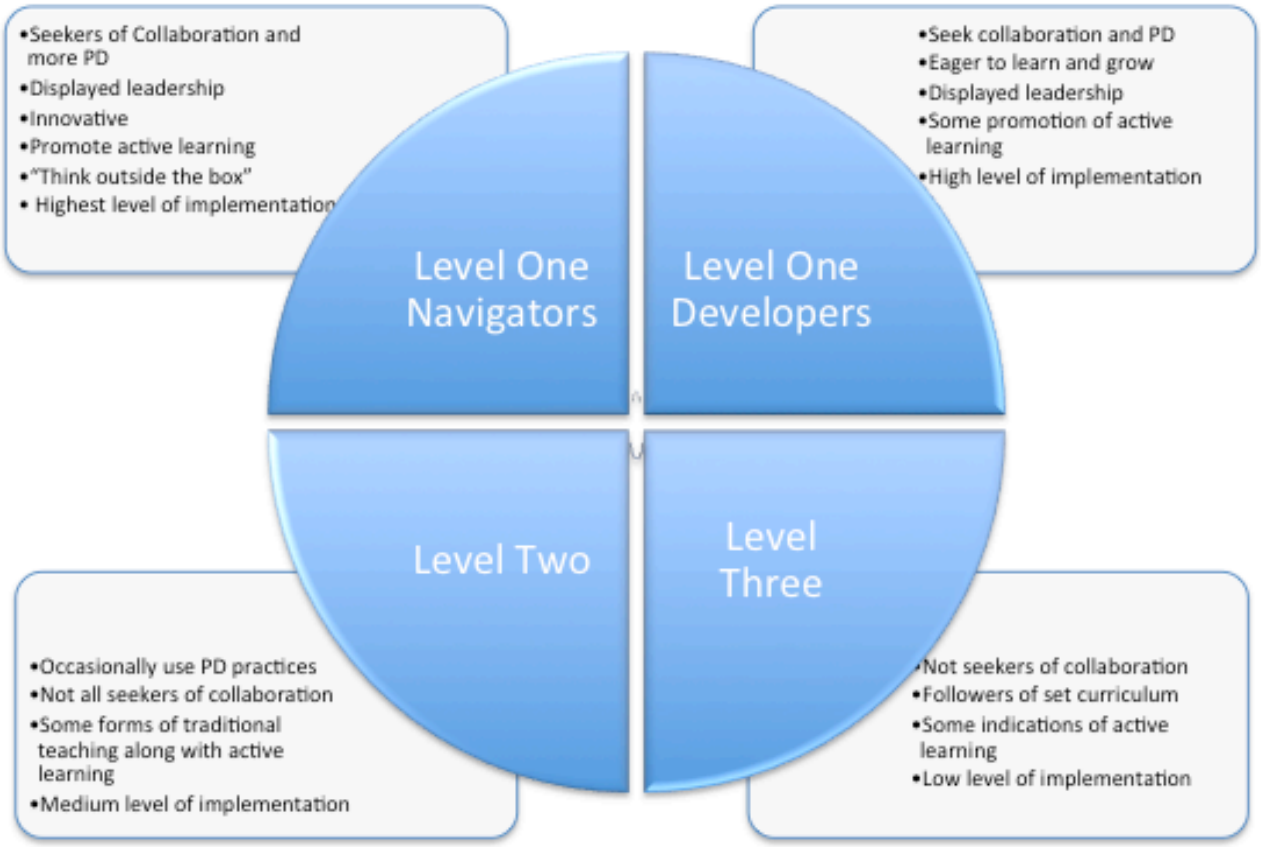
opportunities to collaborate or participate in more PD also still showed evidence of the PD's impact.

Levels of enactment.

Teachers from this PD seemed to present differing levels of enactment of the PD's principles. Knapp and Peterson (1995) described three levels of teachers' continued enactment of PD principles, with teachers who continue to grow and increase in their PD-based practice (level one), those use the PD supported practices occasionally and are consistent in this level of enactment (level two), and those teachers who originally utilized practices consistent with the PD to a greater extent but now do so only occasionally (level three). Miller (2012) described four levels of longevity of PD-related practices: those teachers "who push boundaries" (p. 105) and are driven by the way students learn (Navigators); teachers who seek PD and research-based practices, "promoting change in instructional practices" (p. 104) (Developers); teachers who are "resistant to instructional change" (p. 104) and are more teacher-centered, wanting "to maintain the status quo" (p. 104) (Villagers); and those teachers who are "adrift" from school's mainstream of curriculum or planning, seemed "resistant to new ideas and emphasized personal ownership of classroom instruction" (p. 103) (Drifters). These two frameworks provide a way to describe teachers' adherence to PD related practices over time from the greatest to the least amount. This dissertation synthesized the two frameworks, utilizing the levels described by Knapp and Peterson (1995) but splitting

level one into the two higher levels described by Miller (2012), Navigators (the highest level) and Developers (the second highest level). See Figure 5.

Figure 5: Long-term influence of PD.



Levels adopted from Knapp and Peterson (1995) and Miller (2012).

Level Three.

Level Three contained just one teacher (T15); he discussed implementing a few activities from the PD but chooses now to just follow the set curriculum of his school. His observation showed one student-centered practice, putting students in pairs to discuss problems, but the teacher did not scaffold students' understanding of the purpose of this practice. His interview indicated some change in PCK during the PD but he struggled to describe what he learned. In some comments, this teacher gave indication that he was what Miller (2012) called a Drifter in that he was committed to personal ownership of his teaching. He explained why he did not pursue collaboration: "I knew the content. I knew what I wanted to show them and how I wanted to present it" (T15). This teacher collaborated with his current team only because they were expected to enact the same curriculum.

Level Two.

Level Two, where teachers used PD-supported practices and knowledge occasionally, contained four teachers, T30, T33, T2, and T51. Teachers T33 and T51 discussed how they used interactive technology to have students actively participate in learning and talk about what they learned. There were some elements of traditional teaching in their classroom observations, however, similar to what Miller (2012) described for Villagers. Teacher T30 used calculators in ways learned in the PD to provide some sense of student-centered pedagogy and exploration, but this was

intermixed with a traditional lecture-type environment in his observation. Teacher T2 discussed implementing group work and activities he learned in the PD but also felt he could not make a big difference in his students. He explained: "You know, I can become more enriched myself, but how do I enrich the student?...So it's just like I said before, these kids are at a very basic level, trying to raise them up is extremely difficult. There is a resistance on their part for learning…" He is discussing his students in the alternative school where he teaches; this setting could explain his intermittent implementation of the PD's principles. This teacher (T2) does continue to seek PD opportunities and did describe mentoring other teachers with knowledge he learned during the PD, so perhaps it is mainly his new setting that makes implementation more difficult.

Level One-Developers.

Level One-Developers were teachers who were eager to learn new practices and promote change within themselves and others. They implemented what they learned in the PD and also sought out new PD opportunities. The data from this dissertation indicated Teachers T27 and T62 as Level One-Developers. Teacher T27 took initiative to influence her Algebra I team to teach Linear Equations using a unit based on systems of linear equations that she developed, extending PCK from the PD. Her observation did not present the higher level of implementation of PD-supported active learning pedagogy, however. Teacher 62 talked about projects to support active learning of students and actively sought out collaboration in order to better her practice. Observation of her class

revealed some active engagement of students but some improvement would be necessary to further raise her implementation level to that of Navigators.

Level One-Navigators.

Level One-Navigators had the highest level of implementation of PD practices. As Navigators, these teachers are "thinking outside the box", "are driven by how students learn", "often show evidence of deeper and more reflective practice", "use advanced learning models and cognitive strategies to promote their students' independent thinking and engagement", and are enthusiastic to use knowledge from research to better their practice and increase their knowledge (Miller, 2012, p. 105). Teacher T68 described her "team building" exercises with students, her ability to engage almost all of her students in verbalizing and showing their work through the interactive whiteboard technology, and her striving for more educational and PD opportunities. Teacher T19 also showed a high level of enactment through his interdisciplinary project for students, his active pursuit of new PD opportunities and collaboration with other teachers both in math and other disciplines, as well as evidence seen in his observation of project-based learning and a culture of student learning where they take responsibility for their own learning. This teacher summarized, "I learned so much and tried to apply in my classroom all the available technology to the research-proven teaching strategies." (T19) Another teacher that exemplifies Level One-Navigators in the data from this PD is Teacher T11. This teacher described in his interview multiple ways that he continuously sought out better

ways to meet student needs based on research; he was definitely "thinking outside the box" with ideas for his pre-teach model and modeling student vocabulary development after what was done in foreign language class through the creation of posters for mathematics vocabulary. He mentioned several times seeking out research-based practices and sharing this with his campus through his leadership role as math department chair. During the observation of his classroom, students were writing their own definitions of previously learned vocabulary and making predictions of linear equations, tables and graphs through the use of the calculator.

The data from this dissertation thus present five teachers at either Level One-Developers or Level One-Navigators. Four of the teachers were categorized at Level Two where they still implement PD practices and knowledge occasionally. One teacher was categorized at Level Three, as he used the practices at the beginning of the PD but not as much anymore. Finally, one teacher no longer teaches. Therefore the majority of this sample of teachers still exhibit PD-supported practices and knowledge, revealing a long-term influence on teachers from high school PD based on the theoretical framework adopted in this dissertation.

Summary of long-term influence.

Teacher data from this dissertation show evidence of the duration of the PD's effects. Personal initiative (corresponding to leadership in the theoretical framework) as well as support from others through collaboration seems to affect the level of enactment

of PD-related practices and knowledge today. Teachers who had higher degrees of implementation or increased usage of what was learned in the PD utilized support from others through collaboration, as Knapp and Peterson previously observed (1995). Teachers identified as either Level One-Navigators or Level One-Developers sought collaboration with other teachers in order to better their practices and increase their knowledge, and were determined to further themselves professionally as leaders. Level Two and Level Three teachers, aside from Teacher T2 who had a different type of teaching assignment, seemed to not seek out collaboration or did not have a high level of personal initiative.

Relationship of findings from this dissertation to the literature.

The results from this dissertation demonstrated the longevity of changes in teachers from the PD, a need for PD research according to Kazemi and Hubbard (2008). Indeed, teacher knowledge and practice changed from the PD according to the data and the effect of the PD continued and/or expanded in many teachers. The change in teachers' practice and knowledge during the PD, however, was not found to have significantly affected student achievement.

INTERCONNECTIONS WITHIN THEORETICAL FRAMEWORK

The theoretical framework adopted in this dissertation as seen in Figure 1 was derived from research on PD programs and what elements render them effective.

Desimone (2011) claims there are "interactive relationships among the core features of professional development, teacher knowledge and beliefs, classroom practice, and student outcomes" (p. 70). Throughout axial coding, "relating concepts/categories to each other" (Corbin & Strauss, 2008 p. 198), relationships between the components of the theoretical framework were revealed through the data in this dissertation to support the existence of interactive relationships between the core elements of PD, a previously unexplored topic. This was demonstrated in many examples from the years of the PD as well as after the PD. Collaboration, for example, worked with content to impact teacher change for some teachers. Leadership worked with each of the other framework components to inspire change, in some cases, as well. Content knowledge gained from the program sometimes stimulated active learning pedagogy in teachers.

A contribution of this dissertation is to build knowledge of these processes and interconnections revealing how they possibly work together for some teachers and create a more beneficial PD experience. The following discussion summarizes each of the possible relationships describing how they worked together for some teachers to facilitate teacher change from PD while comparing to current literature on PD. Table 5 presents the evidence from teacher data to support these integrations with total numbers of teachers in the last two columns (data from PD years included all the teachers in the study n=15 and regarding data after the PD four were not able to be contacted therefore n=11). Teacher numbers are in *italics* for evidence gathered during the PD, standard text for evidence

gathered in data from after the PD, and **bolded** indicating evidence from teacher data both during and after the PD, indicating some overlap in evidence and longevity of the PD for those teachers.

Table 5: Evidence for theoretical framework integration.

Framework integration	**Teachers**	**Total number during PD (n=15)**	**Total number after PD (n=11)**
Collaboration influences content	**T2,** *T11, T15,* **T19,** *T22, T25, T27, T30, T35, T51*, **T62**, *T71,* T68	12	4
Content influences active learning pedagogy	**T27**, *T62*, **T68,** *T71*, *T19,* T11, T33, T30	5	5
Content influences leadership	*T19,* **T27**, *T40, T51, T68, T71,* T11	6	2
Collaboration influences active learning pedagogy	*T71*, **T19**, *T62, T68, T33, T27, T51*	6	1
Collaboration influences leadership	**T2,** *T27,* **T11, T68,** *T71, T33*, **T19**	7	4
Leadership influences collaboration	*T2, T19, T11*, **T27**	4	1
Leadership influences active learning pedagogy	**T19, T68,** T11	2	3

Evidence exhibited for teachers during PD (Italics)
Evidence exhibited for teachers after PD (Standard)
Evidence exhibited for teachers during and after PD (Bold)

Collaboration influences Content

Research on collaboration in PD focuses on establishing norms of communication (Borko, 2004) and the development of shared vision (Garet et al., 2001; Loucks-Horsley et al., 2010). However, content, labeled the most important element for effective PD, is not explicitly connected with collaboration in research regarding elements of effective PD (Desimone, 2009; Garet et al., 2001). The research in this dissertation indicated that collaboration was key in development of some teachers' content knowledge and PCK, with twelve teachers indicating this connection during the PD and four demonstrating a continuation of collaboration influencing content after the PD. Teachers felt collaboration in the PD provided a "network of teachers" (T62) to supply resources, give advice on multiple ways of teaching, provide a better understanding of content to be taught, and to exchange ideas, for example. Collaboration is recommended because teachers "need to engage with other teachers in conversations to learn what works under what circumstances, examine examples of practice, and reflect on their own practice and their students' learning to become 'connoisseurs' of effective practice" (Loucks-Horsley et al., 2010, p. 63). Collaboration in this PD seemed to be the catalyst for teacher growth in content knowledge, specifically in PCK for many teachers.

Content influences active learning pedagogy.

Garet et al. (2001) recommend that teachers be engaged in activities centered on content in their PD experiences. However, this dissertation found some teachers' greater

understanding of content knowledge, including PCK, increased their ability to facilitate active learning for students with evidence found for five teachers during the PD and five afterwards. For example, the connection between content knowledge and learning with activity was apparent in the data when teachers discussed TEKS-based games and activities that they employed in their classrooms, as learned and developed in the PD. Observations of teachers using PCK gained from the PD on technology was seen in several teachers' classrooms (T11, T68, T33, T30, T27). The greater knowledge of interconnections with other disciplines and PCK on technology helped teachers design and implement student-centered forms of learning, as well. The research from this dissertation found that greater content knowledge from PD helped some teachers promote active learning pedagogy.

Content influences leadership.

Researchers recommend the development of leadership through PD (Darling-Hammond et al., 1995; Loucks-Horsley et al., 2010). The research in this dissertation indicated a way to encourage this development is through the increase of teachers' content knowledge and PCK. Some teachers grew in leadership as a stance, in confidence to try new teaching methods because of their new understandings. Additionally, some teachers were propelled to mentor others utilizing knowledge they gained from the PD. Therefore, content developed in the PD fostered leadership, with this connection being

strongest during the PD - six teachers during the PD and two afterwards had evidence for content influencing leadership.

Collaboration influences active learning pedagogy.

Research states that some PD programs promote a "generative perspective on learning..." where teachers are "exploring ideas, testing those ideas, and then explaining [to others]" facilitating better understanding (Fishman & Davis, 2006, p. 544).
This dissertation further found that teachers in this PD utilized collaboration both within the PD and with others to share and develop better ways of promoting active learning pedagogy. This revealed the collaboration and exploration promoted and established in the PD went beyond to create a difference in classrooms. This interconnection was strong during the PD with six teachers having demonstrated evidence for collaboration's influence on active learning pedagogy, but only one teacher explicitly mentioned that it continued after the PD.

Collaboration influences leadership.

Prior research on PD explains the development of leadership in teachers as not just an assigned formal role but also involving and including all teachers as they focus on learning and reflect on practice, taking on the stance of a professional in education (Darling-Hammond et al., 1995). This dissertation found that collaboration helped bring about this form of leadership in some teachers (seven during the PD and four afterwards)

where they grew in their practices and exhibited confidence in teaching. An example of this is seen in Teacher T68: "…I would say the collaboration, yes…because I then networked with other math teachers, kind of came to better understand the networkings, or whatever. It helped me grow as a person so it helped me grow as a leader also…" Another teacher (T33) talked about how through interactions with others, his confidence grew. Teacher leadership can be fostered through collaboration in PD.

Leadership influences collaboration.

Researchers of PD explain that teachers may develop as leaders as they: "serve as supporters of other teachers, as agents of change, and as promoters of reform" (Loucks-Horsley et al., 2010, p. 71). Data from some of the teachers (four during the PD and one of those afterwards) indicated content knowledge and PCK being learned in PD created leadership as a stance where teachers wanted to share with other teachers, in turn creating more collaboration. For example, teachers (T2, T19, T11, T27) described evidence that they took on leadership roles and then shared and collaborated with other teachers. For example, Teacher T2 in his interview talked about mentoring other teachers through frequent collaboration and evidence for this was seen in his written reflections as well. He writes: "I was able to bring fresh ideas into the classroom and also share these ideas with non-[PD] colleagues." Thus, again, content was the key for leadership to develop in order that teachers would be propelled to share and collaborate with others.

Leadership influences active learning pedagogy.

Darling-Hammond and colleagues (1995) claim "that teacher leadership is inextricably connected to teacher learning" (p. 89). In the PD described in this dissertation some evidence (two teachers during the PD and three afterwards) was presented, in what teachers described as more confidence developed through the PD, and the ways leadership as a stance supported active learning pedagogy. Some teachers explained that after the PD they created and invented even more student-centered forms of learning like vocabulary posters (T11), projects that integrated disciplines (T19), and team building forms of problem solving (T68). Leadership created in teachers the ability and confidence to implement and innovatively create forms of student-centered pedagogy.

Conclusions.

Data from this dissertation supported the idea in prior literature that content, active learning, collaboration, and leadership are key components of long-term, effective PD. It further revealed interconnections between the theoretical framework components describing ways some teachers learn and develop from PD experiences (presented in Table 5). Evidence for these connections in prior PD research is sparse, with little detail on the mechanisms or other details of the interconnections. These relationships between the elements are not well defined in literature on effective PD (Desimone, 2009; Garet et al., 2001; Loucks-Horsley et al., 2010), and this dissertation study produced evidence that

the elements of effective PD interact with one another to effect change for some teachers. In doing so, this dissertation proposed a new level in the framework for effective PD, focusing on the interactions and interconnections among the components. The relationships among elements of effective PD found in data from this dissertation should be further evaluated for congruence with other PD programs. Since benefits to teacher development from PD were revealed for some teachers, future PD programs can experiment with further fostering the interactions of effective PD elements and investigate this new level in the framework for effective PD.

LIMITATIONS

The study conducted for this dissertation has limitations, however. Regarding student assessment data one possible limitation was these data were not identifiable by teacher, only by grade level at each school. This could hinder the findings because perhaps some teachers were not implementing PD-supported practices as much as others. For example, one teacher, a department chair, mentioned in her interview that one 9th grade teacher at her school was not providing PD-related practices (the teacher reportedly showed videos unrelated to mathematics in her classroom often) in her Algebra I class and the 9th grade scores in that classroom reportedly dropped, skewing the results for that grade-level. That school's 9th grade percent passing decreased by two percent from before the PD to afterwards according to the data. Since only grade-level for each school was utilized, teacher variability was not taken into account.

Also, due to teacher turn over in School 1, at least half of the teachers in the PD were not in the school the two years before, therefore the performance of students of different teachers was compared. Teacher-specific data could have allowed a more complete picture of student change specifically of teachers who were in the PD. This lack of continuity in School 1 from before the PD to during the PD causes an incomplete measure of teacher to student influence and therefore affects the reliability and validity of the findings. However, School 2 had a consistent teacher population from the pre to post PD period as identified in this dissertation, so the limitation of lack of continuity was specific to School 1 only.

Additionally, if student assessment data had been studied by teacher perhaps this would have allowed comparisons to be made between the teachers with different levels of enactment of PD principles discussed previously. This dissertation's data exhibited teachers enacting practices from the PD to various degrees, so data by teacher could have perhaps demonstrated a relationship between teacher change in practice and improved student achievement. Also, mentioned previously, some research states that standardized assessment's ability to measure changes in instruction and thereby student achievement according to those changes, is in question (Pham et al., 2009, pp. 180, 186). Perhaps a more accurate picture of student achievement could come from assessment in teachers' classrooms or a better form of standardized assessment that could be traced back to the teacher.

Regarding the assessment of students, as with any standardized test, student performance depends on matters outside of school such as family concerns or sickness. With results relying on data from one particular day, a host of issues could affect students such as inadequate rest or nourishment, problems with friends, health issues, etc.

Moreover, the PD was not directly aligned with all of the content in the tested in the TAKS. There were TAKS tests objectives that were not included in the PD's content. The TAKS is a comprehensive instrument covering content from 8th grade, Algebra and Geometry, whereas this PD emphasized Algebra content with some Geometry. Although the majority of the TAKS assessment in all grade-levels tests students on algebra-related topics, there is a possible misalignment with the assessment used to gauge student understanding and test the hypothesis that PD works through teacher change in practice and knowledge to affect student achievement.

Another possible limitation regarding the investigation of student assessment was the usage of passing rate other than actual student scores. The state decides each year the number of questions correct to demonstrate standards have been met. When a student reaches this number of questions, they receive the rating of "met standards". This dissertation utilized data that indicated the percent of students in each grade level that met the standards as set by the state that year, in other words a passing rate. Students could have scores that barely meet this standard, be perfect, or somewhere in between. Therefore, student variability is not fully taken in to account when student assessment is

measured in this manner, providing another possible limitation that could have hindered finding a relationship between PD and student achievement. Research summarizes: "…measuring both student learning and teacher knowledge involves a host of issues related to assessment and test construction" (Desimone, 2009, p. 188). Limitations in measuring student achievement are unavoidable in research and although this research utilized a standardized assessment instrument some issues still exist that prevent a complete picture of teachers' possible change in practice and knowledge and its possible effect on student achievement.

Furthermore, the "Algebraic Ideas" assessment used to investigate the change in teachers' content knowledge and PCK was not especially designed for the PD or this dissertation study. The researcher did not have access to the individual questions on the test or teachers' results on individual questions. Without having the access to the questions, the rigor of the content or pedagogy items or what topics in Algebra were covered is unknown. Also, as with all tests, teachers' performance can be affected by personal issues or possible sickness as well.

Also, aside from the "Algebraic Ideas" assessment, all data were teacher self-reported for the PD years. The interviews were conducted two years after the PD, which relied only on the teachers' memory of what happened during the PD through self-report as well. Self-reported data is controversial with some research indicating correlations with observational data, suggesting reliability; however, researchers usually report

possible bias and limitations with the use of self-reported data (Desimone, 2009). For example, teachers in self-reported data could possibly be presenting themselves favorably as research has documented "self-presentation bias or social desirability bias" (Kopcha & Sullivan, 2007, p. 628) where participants present themselves favorably. Additionally, "relying on self-reports of behavior might provide a too-optimistic view of the effects of a program" and "research shows that teachers overreport their implementation of professional development and other reforms" (Desimone, 2009, p. 190). Thus the data on teacher change from interviews and written reflections may not present a complete picture of actual teacher transformation from PD. Issues with teacher self-report are difficult to avoid; however, triangulation of data with self-reports being complemented with classroom observations and the "Algebraic Ideas" assessment provide a measure of protection against social desirability bias. In general, observational data were congruent with the self-reported data.

Additionally, a possible limitation is perhaps there was not enough time for teacher change to result in a significant improvement in student achievement. Loucks-Horsley et al (1998) explain: "It is foolhardy to either expect or focus on measuring student learning when teachers have just begun to learn and experiment with new ideas and strategies." (p. 222) (as cited in Desimone, 2009, p. 186). Time is not only necessary for teachers' change and development, but also for students to become accustomed to learning in a more reform-oriented manner, through PD-supported practices. By

observing and interviewing teachers two years after the PD, this study allowed some time but perhaps not enough, for the full impact of the PD to surface. Some teachers continued to expand their practices so student achievement data collected from the years of the PD may not present the complete picture of the indirect effect of high school teacher PD on student performance. Since the assessment in the state changed forms in the years after the PD, this limitation could not be avoided.

High school students are at the end of compulsory education and may be resistant or less cooperative to learn in new ways, presenting another unavoidable limitation with this specific population of students. This could affect the way that students participate in and accept new forms of teaching and learning. The construction of knowledge through active learning takes work and critical thinking and can be challenging for students who are more familiar with lecture types of learning environments.

Another possible limitation was missing data, that is, the four teachers from the two schools that could not be contacted or interviewed. Including the four teachers could have changed the results or provided additional information about student assessment anomalies like the drop in 9th grade for one of the schools. Given that data collection took place two years after the completion of the PD, a lack of the complete original population is common due to teacher turnover and changes in contact information. Longitudinal studies inevitably suffer from attrition. The researcher attempted to reduce attrition by

contacting these teachers in multiple ways, including through other teachers in the program, the PD developer, and following up on new email or school assignment leads.

Additionally, teachers were observed teaching one time and perhaps more observations would have revealed less or more of the PD's influence. More observations can aid in creating reliability of the measurement of teachers' instruction (Desimone, 2009). With one observation, teachers could possibly be presenting practices that reflect a greater alignment with PD because they feel this is expected; observations could also be affected by sickness or other personal issues. However, the observational data was triangulated with interviews, teacher assessment data, and written reflections.

Data from the PD years were limited and not specifically created to answer the research questions proposed. The questions prompting the written reflections were predesigned by evaluators and although these questions had some alignment with content knowledge and collaboration, active learning pedagogy was not specifically addressed and had to be inferred from teacher responses. Additionally, some teachers were explicit in their responses to written reflections, but others were very brief and lacked detail, not providing an adequate picture of teacher change. These issues with teacher data could cause some hindrances in providing answers regarding teacher knowledge and practice during the PD years. Longitudinal data in a dissertation study is difficult to collect due to time constraints, and this dissertation relied on data collected during the PD, before the

dissertation study began. In order to address this limitation, teachers were interviewed and asked about the PD period as well.

SUMMARY AND RECOMMENDATIONS

This dissertation provided a unique look at the longevity of PD effects on high school teachers, as well as effects during the PD on teachers and student achievement. Since research on PD for high school teachers while investigating changes in student achievement is not common (Yoon et al., 2007), this work helped to begin the discussion of what effects long-term PD that is research-based has on teachers and their students, as well as the longevity of those effects, recommended by researchers (Kazemi & Hubbard, 2008). This dissertation outlined this change in teacher knowledge and practice with data from the PD period and two years afterwards utilizing a theoretical framework that is based on research (Desimone, 2009) and recognized by many researchers (e.g., Borko, 2004; Garet et al., 2001; Greenleaf et al., 2011; Loucks-Horsley et al., 2010). This allows linkages and further study to develop so that PD programs for high school teachers can be improved in order to better teachers' practice and knowledge and impact student learning. The results of the research presented in this dissertation allow for some recommendations for researchers, PD developers, administrators, funders of PD, and teachers in PD programs, as outlined below.

Regarding future research, study of PD should utilize elements of effective PD similar to the theoretical framework adopted in this dissertation in order that consistency

and broad conclusions can be made regarding both teacher learning in PD and the longevity of PD's effects. This is recommended by research since a consensus of core features exists (i.e. Desimone, 2009; Garet et al., 2001; Loucks-Horsley et al., 2010); these elements should be addressed in evaluating PD's effectiveness "to allow studies to build on each other and refine and expand our knowledge base" (Desimone, 2009, p. 183). By studying similar elements of PD, research allows for comparison across studies both regarding teacher change and learning during PD and how these effects are modified, extended or decreased after the PD. This dissertation contributed to this framework by identifying interconnections across the components as a potentially important level of the framework. Future research should analyze data for these specific interconnections in order to shed light on how these may vary by context; it should also seek out other such interconnections.

This dissertation researched teacher change in knowledge and practice from high school PD and found a long-term influence of the PD's effects in each of the theoretical framework elements. Future research into PD should build in a pre- post- delayed design in order to fully account for the effect of PD, with delayed data collection even longer past the PD than the present study's period of two years.

PD developers, administrators and funders of PD should consider the inclusion of the elements of content (with a focus on content that is coherent to teachers needs and practice), active learning, collaboration and the fostering of leadership in long-term

experiences providing PD for teachers. According to the data presented in this dissertation, these elements are not only demonstrated in teacher change from PD and continue to develop in the long-term, but in addition the elements work together for some teachers to facilitate change as described previously. For example, without facilitating a culture of collaboration with teachers, the development of some teachers' content knowledge and PCK, active learning pedagogy, and teacher leadership may not advance as much. As some teachers collaborate with one another sharing and learning PCK and active learning pedagogy, they advance and grow to become leaders, as described for Professional Development Schools in Darling-Hammond et al. (1995).

Teachers looking for effective PD programs to enrich their practices should select those that include core elements of effective PD, similar to those adopted in this dissertation. Teachers who desire change and development from these experiences benefit from programs such as the one studied in this dissertation where a long-term content focus is supported through active learning and the fostering of both collaboration and leadership. This can facilitate teacher development and change, which can lead to growth in other teachers through collaboration and leadership.

Also, the data from this dissertation indicated that a richer understanding of content knowledge developed when teachers had opportunities to advance understanding across topics within the discipline of mathematics and make connections with other disciplines as well. This means that a focus on content in PD does not have to be limited

to the particular subject of the teachers as teachers benefit and glean important strategies from across the discipline of mathematics, for example. However, the focus on content should be coherent to the teachers curriculum and school's needs. Also, PD for mathematics can facilitate experiences with science departments so that cross-disciplinary connections can be fostered in PD. When PD experiences provided for teachers create opportunities to study content that is coherent, teachers expand their understanding and can provide learning experiences for students based on this knowledge.

The study conducted in this dissertation concentrated on two schools where all the teachers of Algebra I and Algebra II attended the PD. Further PD research on the effect of participation within a school would be informative. The teachers in this study had a built-in community to support them. How would a teacher who was the sole participant in PD at her campus develop differently? The effects could well be different without a complete team of support. Also, since effects on teachers from the PD were found, PD developers and administrators should consider providing opportunities for entire content teams from schools to attend long-term PD concurrently and together in order to better facilitate teacher change and collaboration to enrich that change.

Since the few studies investigating both teacher change in knowledge and practice from PD and the effects of this change on student achievement in upper grades are mixed, more research with differing types of assessment (rather than only standardized

assessment) would be beneficial as well. Teacher-level data would be invaluable in tracing the effects from PD to teacher change to student achievement. Additionally, teacher-level data could help comparisons to be made across teachers who exhibited different levels of enactment. Also, PD research should be carried out over a longer period of time (post-PD); such research would perhaps show more effect on student achievement with more time to allow for both teacher change and student change. In summary, the research conducted in this dissertation leads to concrete recommendations for the study of PD, development of PD, and selection of PD experiences by teachers. Researchers and developers of PD should consider including entire content area teams and/or the study of how PD experienced as a large population of teachers from one school differs from the experience of teachers in schools with fewer participants. In order to study the indirect effect of teacher PD on student achievement, differing forms of assessment should be utilized and these should be connected with the particular teacher in the PD. Developers of PD or administrators should include in the PD the study of content that is coherent for teachers' experiences and that span other subjects in the content area and across disciplines in order to enrich teachers' knowledge of content knowledge and PCK. Evaluation of teacher practice and knowledge changes from PD and the effects of these on student achievement should allow enough time for the change to foster and develop. Teachers, when selecting PD programs, should consider participating in long-term opportunities that contain elements of effectiveness, that is content (coherence),

active learning pedagogy, collaboration and leadership, as these were found to interconnect and enhance some teachers' learning and development.

Appendix A: IRB approval letter

OFFICE OF RESEARCH SUPPORT

THE UNIVERSITY OF TEXAS AT AUSTIN

P.O. Box 7426, Austin, Texas 78713 · Mail Code A3200
(512) 471-8871 · FAX (512) 471-8873

FWA # 00002030

Date: 06/02/14

PI: Tina Louise Vega

Dept: Science, Technology, Engineering and Mathematics

Title: Professional Development's Long-Term Effect on Teacher Knowledge and Practice

Re: IRB Expedited Approval for Protocol Number 2013-10-0042

Dear Tina Louise Vega:

In accordance with the Federal Regulations the Institutional Review Board (IRB) reviewed the above referenced research study and found it met the requirements for approval under the Expedited category noted below for the following period of time: 05/30/2014 to 05/29/2015 . *Expires 12 a.m. [midnight] of this date.* If the research will be conducted at more than one site, you may initiate research at any site from which you have a letter granting you permission to conduct the research. You should retain a copy of the letter in your files.

Expedited category of approval:

☐ 1) Clinical studies of drugs and medical devices only when condition (a) or (b) is met. (a) Research on drugs for which an investigational new drug application (21 CFR Part 312) is not required. (Note: Research on marketed drugs that significantly increases the risks or decreases the acceptability of the risks associated with the use of the product is not eligible for expedited review). (b) Research on medical devices for which (i) an investigational device exemption application (21 CFR Part 812) is not required; or (ii) the medical device is cleared/approved for marketing and the medical device is being used in accordance with its cleared/approved labeling.

☐ 2) Collection of blood samples by finger stick, heel stick, ear stick, or venipuncture as follows: (a) from healthy, non-pregnant adults who weigh at least 110 pounds. For these subjects, the amounts drawn may not exceed 550 ml in an 8 week period and collection may not occur more frequently than 2 times per week; or (b) from other adults and children2, considering the age, weight, and health of the subjects, the collection procedure, the amount of blood to be collected, and the frequency with which it will be collected. For these subjects, the amount drawn may not exceed the lesser of 50 ml or 3 ml per kg in an 8 week period and collection may not occur more frequently than 2 times per week.

☐ 3) Prospective collection of biological specimens for research purposes by non-invasive means. Examples:
   (a) Hair and nail clippings in a non-disfiguring manner.
   (b) Deciduous teeth at time of exfoliation or if routine patient care indicates a need for extraction;
   (c) Permanent teeth if routine patient care indicates a need for extraction.

(d) Excreta and external secretions (including sweat).
(e) Uncannulated saliva collected either in an un-stimulated fashion or stimulated by chewing gumbase or wax or by applying a dilute citric solution to the tongue.
(f) Placenta removed at delivery.
(g) Amniotic fluid obtained at the time of rupture of the membrane prior to or during labor.
(h) Supra- and subgingival dental plaque and calculus, provided the collection procedure is not more invasive than routine prophylactic scaling of the teeth and the process is accomplished in accordance with accepted prophylactic techniques.
(i) Mucosal and skin cells collected by buccal scraping or swab, skin swab, or mouth washings.
(j) Sputum collected after saline mist nebulization.

☐ 4) Collection of data through non-invasive procedures (not involving general anesthesia or sedation) routinely employed in clinical practice, excluding procedures involving x-rays or microwaves. Where medical devices are employed, they must be cleared/approved for marketing. (Studies intended to evaluate the safety and effectiveness of the medical device are not generally eligible for expedited review, including studies of cleared medical devices for new indications).
Examples:
(a) Physical sensors that are applied either to the surface of the body or at a distance and do not involve input of significant amounts of energy into the subject or an invasion of the subject's privacy.
(b) Weighing or testing sensory acuity.
(c) Magnetic resonance imaging.
(d) Electrocardiography, electroencephalography, thermography, detection of naturally occurring radioactivity, electroretinography, ultrasound, diagnostic infrared imaging, doppler blood flow, and echocardiography.
(e) Moderate exercise, muscular strength testing, body composition assessment, and flexibility testing where appropriate given the age, weight, and health of the individual.

☒ 5) Research involving materials (data, documents, records, or specimens) that have been collected, or will be collected solely for non-research purposes (such as medical treatment or diagnosis).
Note: Some research in this category may be exempt from the HHS regulations for the protection of human subjects. 45 CFR 46.101(b)(4). This listing refers only to research that is not exempt.

☒ 6) Collection of data from voice, video, digital, or image recordings made for research purposes.

☒ 7) Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies.
Note: Some research in this category may be exempt from the HHS regulations for the protection of human subjects. 45 CFR 46.101(b)(2) and (b)(3). This listing refers only to research that is not exempt.

☒ Use the attached approved informed consent document(s).

☐ You have been granted a Waiver of Documentation of Consent according to 45 CFR 46.117 and/or 21 CFR 56.109(c)(1).

☐ You have been granted a Waiver of Informed Consent according to 45 CFR 46.116(d).

Responsibilities of the Principal Investigator:

1. Report immediately to the IRB any unanticipated problems.

2. Submit for review and approval by the IRB all modifications to the protocol or consent form(s). Ensure the proposed changes in the approved research are not applied without prior IRB review and approval, except when necessary to eliminate apparent immediate hazards to the subject. Changes in approved research implemented without IRB review and approval initiated to eliminate apparent immediate hazards to the subject must be promptly reported to the IRB, and will be reviewed under the unanticipated problems policy to determine whether the change was consistent with ensuring the subjects continued welfare.

3. Report any significant findings that become known in the course of the research that might affect the willingness of subjects to continue to participate.

4. Ensure that only persons formally approved by the IRB enroll subjects.

5. Use only a currently approved consent form, if applicable.
   Note: Approval periods are for 12 months or less.

6. Protect the confidentiality of all persons and personally identifiable data, and train your staff and collaborators on policies and procedures for ensuring the privacy and confidentiality of subjects and their information.

7. Submit a Continuing Review Application for continuing review by the IRB. Federal regulations require IRB review of on-going projects no less than once a year a reminder letter will be sent to you two months before your expiration date. If a reminder is not received from Office of Research Support (ORS) about your upcoming continuing review, it is still the primary responsibility of the Principal Investigator not to conduct research activities on or after the expiration date. The Continuing Review Application must be submitted, reviewed and approved, before the expiration date.

8. Upon completion of the research study, a Closure Report must be submitted to the ORS.

9. Include the IRB study number on all future correspondence relating to this protocol.

If you have any questions contact the ORS by phone at (512) 471-8871 or via e-mail at orsc@uts.cc.utexas.edu.

Sincerely,

James P. Wilson

James Wilson, Ph.D.
Institutional Review Board Chair

Appendix B: Interview protocol

Student achievement

-Describe the your own students' achievement while you were in the professional development. How does it compare to before the professional development? (Regarding state assessments? Your own formative assessment?)

-Did your PD experience have an effect on your students' achievement and if so, in what ways? Did the PD aid your ability to engage minorities or help you close gaps in achievement between students with low SES compared to those in wealthier districts ?

-Describe what interventions were provided for students for the years of the PD.

-Were there after school programs? Pull-outs? Change in curriculum from 2 years before PD through the PD? Other possible causes for increased student achievement in math?

Content and pedagogy knowledge

-Was your understanding of concepts related to your area of teaching enriched or expanded from your PD experience? If so, what ways? How did this expanded depth of knowledge help you in your teaching? How has your deeper understanding of this content increased your awareness of the interconnection to other conceptual areas and topics?

- Did your PD experience impact your thinking about teaching and learning? If so, Discuss how these ideas helped you plan and explore new teaching methods as a result during your years of the PD. Do you feel like you continue exploring new methods base on your PD experience?

-In what ways, if any, did participation in the professional development affect you in planning and implementing your lessons? During the PD? Today?

-What changes occurred in your teaching as a result of the professional development? During the PD? Today?

-Did your experience alter your beliefs in ways students learn mathematics, and if so, in what ways? During the PD? Today?

Collaboration

- Describe how you communicate and collaborate with your fellow teachers? How do or could these collaborations enrich your practice?

- Did the PD change they way you collaborated with teachers within your school? If so, in what ways? Did the collaboration aid the implementation of things learned in the PD? Do you have an example?

-How about collaboration with teachers in the PD? Can you describe? During PD? Today?

Leadership

- How do you perceive yourself before the PD related to after regarding leadership ability?

- In what ways, if any, did the PD enable you to become a leader on your campus or in the area of sharing knowledge with other teachers? If yes, in what ways have you served

in leadership? (i.e. Role on campus? Presentation at a conference?) (depending on response probe for whether this occurred during the PD or after)

Interviews before and/or after observations

-What content objectives do you hope to cover in this lesson?

-What will the students be doing? Briefly how will the lesson be carried out with the students? (groups, technology, activity, etc.)

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