AN OUTCOME EVALUATION STUDY OF THE IMPACT OF INTENSIVE AND ONGOING PROFESSIONAL DEVELOPMENT ON TEACHER CONTENT KNOWLEDGE AND TEACHER PEDAGOGICAL KNOWLEDGE

A thesis presented
by
Carrie Adams Soliday

to
The School of Education

In partial fulfillment of the requirements for the degree of Doctor of Education

in the field of

Education

College of Professional Studies
Northeastern University
Boston, Massachusetts
February 2015
Abstract

The purpose of this outcome evaluation study is to investigate the impact of intensive, ongoing professional development on teacher content knowledge, teacher pedagogical knowledge and perception of the presence of the core features of effective professional development. The framework for effective professional development informed the design and analysis of this mixed qualitative and quantitative study. In addition, a literature review of professional development is provided to inform the study. The research questions are as follows: (1) What is the impact of an intensive, on-going professional development on K-8 teachers’ mathematical content knowledge? (2) What is the impact of an intensive, on-going professional development program on K-8 teachers’ pedagogical knowledge? (3) How did teachers of grades K-8 perceive the presence of the core features effective professional development in the intensive, ongoing professional development? A outcome evaluation study was used to determine the impact of sponsorship, contact hours, collective participation, sustained time, focus on content knowledge, active learning, coherence, and public examination of practice on the outcome of enhanced knowledge and skill of the participants in a ten-week, intensive, ongoing professional development program. It is evident that utilization of the framework for effective professional development impacts teacher content knowledge and teacher pedagogical knowledge. The analysis of the intensive, ongoing professional development program potentially informs other professional development providers with practices to improve the outcomes of teacher professional learning.

Keywords: effective professional development, teacher content knowledge, teacher pedagogical knowledge, teacher in-service, professional development
Acknowledgements

It is with deep gratitude that I acknowledge my family and the sacrifice of time and presence they have made throughout this journey. To my children, Jordan and Jack, I may have started this work for you but I finished it for me. Thank you for your patience, understanding, and willingness to help out when I needed it the most. To my parents, Ken and Linda Adams, you have always been my biggest supporters, models of work ethic, and unconditional love – thank you! To Keith, thank you for being my personal cheerleader!

Thank you must also be given to the Lincoln Intermediate Unit 12 and the National Institute of Advancing Teaching and Learning for allowing me to conduct this study on an intensive, ongoing professional development program. To Eagle Eye Bobbye Dillman, for serving as my editor-in-chief; relentlessly pointing out my run-on sentences and lack of explanation in every paper submitted for this program! Thank you also Dr. Michael Thew and Dr. Donald Burkins for “paying it forward.” I deeply appreciate you answering the call to serve as third readers and members of the defense committee. And thank you to Dr. Chris Unger for pushing me to the highest of expectations with this research study. I can honestly say, “I have learned so much from the process!”
# Table of Contents

Abstract ......................................................................................................................... 2

Acknowledgements ....................................................................................................... 3

Table of Contents .......................................................................................................... 4

List of Figures ............................................................................................................... 8

List of Tables ............................................................................................................... 9

Chapter I: Introduction ............................................................................................... 10

  Statement of Problem ............................................................................................... 10

  Significance of the Problem ...................................................................................... 12

  Positionality Statement ............................................................................................ 17

  Research Questions .................................................................................................. 18

  Theoretical Framework ............................................................................................. 19

Chapter II: Literature Review ..................................................................................... 21

  Teachers’ Mathematical Content Knowledge ......................................................... 22

  Teachers’ Pedagogical Content Knowledge ............................................................... 25

  Society’s Expectation for Effective Professional Development ............................... 28

  Effective Professional Development ....................................................................... 29

  Perspective of Professional Development ............................................................... 30

  The Research on Ongoing Professional Development ............................................. 38

  Summary .................................................................................................................... 41

Chapter III: Research Design ...................................................................................... 43

  Methodology .............................................................................................................. 43

  Study Context ............................................................................................................ 48
Participants..................................................................................................................51
Design..........................................................................................................................53
Professional Development Needs Assessment...............................................................54
Pennsylvania State System of Assessment.......................................................................55
Recruitment of Participants........................................................................................58
Data Collection...............................................................................................................59
Instruments.....................................................................................................................59
  Diagnostic mathematics assessment for elementary/middle school.........................59
  End of course evaluation............................................................................................60
  End of program questionnaire....................................................................................63
Data Analysis..................................................................................................................65
  Preparation of the data file........................................................................................65
  Item scoring................................................................................................................65
  Knowledge type scores..............................................................................................66
  Subcategory scores....................................................................................................66
  Total scores...............................................................................................................67
Choice of Statistical Techniques....................................................................................68
Reliability, Validity and Generalizability........................................................................69
Protection of Human Rights........................................................................................71
Summary........................................................................................................................72
Chapter IV: Research Findings.......................................................................................73
  Reporting of the Findings and Analysis....................................................................73
  Study Context..............................................................................................................74
Research Findings……………………………………………………………………….76
Analysis………………………………………………………………………………….79
Research Question 1…………………………………………………………………..79
Research Question 2…………………………………………………………………….95
Research Question 3……………………………………………………………………101
Summary………………………………………………………………………………..111
Chapter V: Discussion…………………………………………………………………………112
Summary of the Study……………………………………………………………………..112
Summary of the Findings……………………………………………………………….115
Findings in Relation to the Theoretical Framework……………………………………120
Findings in Relation to the Literature Review………………………………………….130
Limitations……………………………………………………………………………...149
Relationships to the Research…………………………………………………………151
Implications for Practice………………………………………………………………..154
Recommendations for Further Research……………………………………………156
Conclusion………………………………………………………………………………158
Appendices………………………………………………………………………………161
Appendix A………………………………………………………………………………161
Appendix B………………………………………………………………………………164
Appendix C………………………………………………………………………………166
Appendix D………………………………………………………………………………192
References…………………………………………………………………………………194
List of Figures

Figure 1. Framework for Effective Professional Development………………………………….21

Figure 2. End of Program Evaluation Perceived Professional Development Continua……….47

Figure 3. PSSA Mathematics Sample Item………………………………………………………….56

Figure 4. Professional Development Marketing Email………………………………………….59

Figure 5. Professional Development Informational Flyer……………………………………….59

Figure 6. Tri-plot of Content Knowledge, Pedagogy and Cognition………………………….60

Figure 7. Diagnostic Teachers Assessments Mathematical Subcategories…………………..67
List of Tables

Table 1: *End of Program Evaluation Rating Instructor’s Facilitation*

Table 2: *Participants’ Teaching Assignment*

Table 3: *Participants’ Certification Area*

Table 4: *Participants’ Experience & Gender*

Table 5: *Number of College Math Courses Completed*

Table 6: *Elementary Teachers Knowledge Level Scores from Pre- to Post-test*

Table 7: *Middle School Knowledge Level Scores from Pre- to Post-test*

Table 8: *Elementary Teachers Pre- to Post-test Scores by Knowledge Level*

Table 9: *Middle School Teachers Pre- to Post-test Scores by Knowledge Level*

Table 10: *Frequency of Elementary Teachers Pre- and Post-test scores by Subcategories*

Table 11: *Frequency of Middle School Teacher Pre- and Post-test Scores by Subcategories*

Table 12: *Elementary Teacher Pre- and Post-test Raw Scores by Subcategory*

Table 13: *Middle School Teacher Pre- and Post-test Raw Scores by Subcategory*

Table 14: *Participant Perception of Pedagogical Influences*

Table 15: *Frequency of Responses Rating Presence of Core Features*

Table 16: *Perceived “Best” Feature of Professional Development Program*

Table 17: *Perceived “Worst” Feature of Professional Development Program*

Table 18: *End of Program Evaluation Suggestions*

Table 19: *Difference in Total Scores from Pre- to Post-test*

Table 20: *Participants’ Public Examination of Practice*

Table 21: *Participants’ References to Mathematical Pedagogical Content Knowledge*

Table 22: *Participants’ References to Public Examination of Practice*
Table 23: Distribution of Request from the Professional Development Needs Assessment

Table 24: Matching Standards of Math Practices to Participants’ Responses

Table 25: Participants’ References to Coherence

Table 26: Participant Reflections on Core Features of Professional Development
Chapter I: Introduction

Statement of Problem

Professional learning is a common practice for many occupational fields including education (Webster-Wright, 2009). The increase in teacher content knowledge and teacher pedagogy is believed to directly impact students’ achievement causing the success of educational reform initiatives to be dependent upon the content knowledge and pedagogical skills of teachers (Hiebert, Gallimore & Stigler, 2002). The Improving Teacher Quality Grant Programs (Title II) are a major component of the No Child Left Behind legislation and the Eisenhower Professional Development Program under Title II of the Elementary and Secondary Education Act (ESEA) and Title II, Part B under the revised ESEA are the federal government’s largest investment designated to developing the knowledge and skills of classroom teachers in math and science (Birman, Garet, Porter, Desimone, & Herman, 1999). Empirical research on effective professional development for in-service teachers over the last 20 years remains unchanged.

The support and training U.S. teachers typically receive is expensive, episodic, myopic, and often meaningless (Hunt, 2009). Enabling educational systems to significantly impact student achievement requires much more intensive and effective professional learning than has been available historically in the U.S. (Hunt, 2009). “Standardized management paradigm” is the descriptive phrase Kesson and Henderson (2010) use to describe the educational practice of focus on the problem of test performances and its solution of scripted or prescribed curriculum and instruction. Professional development opportunities may look like the classic “in-service” day with outside experts brought in for infusions of new concepts or product implementation training by consultants tied to corporate-created curricula. Many initiatives are fragmented, top-down, and embody a passive view of the teacher who is “empty or deficient, lacking in skills,
needing to be filled up and fixed with new techniques and strategies (Fullan & Hargreaves, 1996, p.17).” As a result the educational systems of the United States, including those in south central Pennsylvania, are squandering a significant opportunity to improve teachers content knowledge, strengthen professional pedagogies and inspire ethical fidelity. In fact, professional development providers promote professional development practices to public schools, charter schools, non-public schools, alternative education sites and special education programs that contradict with disciplinarity and ethical fidelity.

In other words, many teachers learned to teach using a model of teaching and learning that focuses heavily on memorizing facts without emphasizing the application of subject knowledge leaving teachers unprepared to implement teaching practices based on curricular standards that require application of subject knowledge (Cohen, 1990; Elmore & Burney, 1996; Elmore, Peterson, & McCutcheon, 1996; Grant, Peterson, & Shojgreen-Downer, 1996; Sizer, 1992; McLaughlin & Talbert, 1993; Darling-Hammond & McLaughlin, 1995; Porter & Brophy, 1988). The educational reforms of the Common Core State Standards (2010) emphasize implied cognitive capacities in English Language Arts and explicitly stated mathematical practices to create habits of the mind that cannot be memorized. Instruction aligned to the cognitive reading strategies and mathematical practices expressed in the Common Core State Standards equates to Depth of Knowledge 3: Strategic Thinking and Depth of Knowledge 4: Extended Thinking (Webb, 2006; Hess, 2009). It is the ethical and democratic responsibility of educators to deepen their understanding of their discipline in order to reach the expectations of the educational reform movement and ultimately increase student achievement.
Significance of the Research Problem

Freire’s (1974) warned that a program presented to the people from a predetermined point shows fear of change, while curricular leadership of a community of learners supports the personal, academic, and/or professional growth of the educational membership. In other words, while fear often prevents the desire and flexibility to change rigid models (Flinders & Thornton, 2013) a curricular leader in possession of the essential components that characterize leaders in a knowledge society can counterbalance fear. According to Fullan (2002) those characteristics include moral purpose, understanding of the change process, the abilities to improve relationships, to create and share knowledge, as well as build coherence. The instructional climate is a reflection and extension of the professional leaderships’ actions. Furthermore, good leaders develop leadership skills in those around them by giving others opportunities to voice ideas, propose actions, and reflect on practice. Ongoing support in the form of collaboration, action research, scaffolding, goal setting, and reflection continues the cycle of transferrable learning in the educational setting.

The written, taught and assessed curriculum should be a reflection of the mission of schooling and long-term transfer goals; those skills all students should possess when they complete an educational experience (Wiggins & McTighe, 2012). Examples of long term transfer goals for youth include read to understand texts; write to address intended audience; gather evidence to create a clear and coherent message; communicate effectively; and listen actively. Those sorts of targets are not completed in a unit, course, or semester; they are completed over a student’s educational experience, life experiences, self-education, and other learning that may extend beyond formal school structures. For educators, long-term transferrable goals include: goal setting, data collection, analysis and interpretations of data, reflection of
practice, and the refinement of educational plans. Curricular leaders following a re-constructivist theoretical stance view education as social reform and change for a better society, aligning curriculum with long-term transfer goals and the mission of schooling.

Kessen and Henderson (2010) use the term disciplinarity, to describe systemic professional development focused on the “subject matter that teachers will be teaching and on how students learn the particular subject matter (p. 215).” Disciplinarity coupled with ethical fidelity, the way an individual is caught up in the wave of an emerging truth (Badiou, 2001), transforms professional development. “The possibility of ethical fidelity arises when one comes to understand the co-dependency of freedom and responsibility that accompanies a commitment to the path of democratic wisdom (Kesson & Henderson, 2010, p. 226).” Presented as a challenge to educators, the democratic wisdom challenge is to go beyond the standardized, technical practices of teacher preparation and professional development to deep subject matter understanding integrated with democratic self and social learning. Furthermore, the understanding of disciplinary artistry is built upon the definitions of curriculum disciplinarity (Pinar (2007) and ethical fidelity (Badiou, 2001) as well as Dewey’s (2004) pedagogical beliefs. Dewey (2004) posits the neglect of the fundamental principle of the school as a form of [democratic] community is the cause of education failures and employs every teacher to realize the dignity of the calling of education. Essentially, Pinar (2007), Badiou (2001), Kesson and Henderson (2010) amplify, elaborate and attempt to refine Dewey’s challenge from the late 1800’s in a more contemporary light.

In this sense, educators with their unique callings and who are committed to the idiosyncrasies of their art are also comfortable with differentiated and disciplined (subject) based professional development (Kesson & Henderson, 2010). Pinar’s (2007) concept of curriculum
disciplinarity and geometric model expands upon the notion of democratic education and guides the theory of discipline artistry. In Pinar’s model, the vertical dimension, the intellectual history of the discipline (curricular area), intersects with the horizontal dimension, the analyses of and experience with the field’s present set of intellectual circumstances including current crisis (events) in democracy. Kesson and Henderson add a third dimension, a diagonal dimension that is implied in Pinar’s model (2010). The diagonal dimension refers to the dynamic personal understandings and broadening of thought generated at the vertical-horizontal interface. At this junction, the courageous educator engages in ethical fidelity to uncover the emerging “truth” or new understanding (Badiou, 2001).

According to Grimmett & MacKinnon, (1992), Huberman (1989), Richardson and Placier, (2001) teachers rarely draw from a shared knowledge base to improve their practice, to routinely locate and translate research-based knowledge to inform their efforts. Additionally, models of professional learning have been perpetuated that conflict with a significant body of research indicating that effective professional development is ongoing, active, social, and related to the professionals’ work (Garet, Porter, Desimone, Birman, Yoon, 2001). Webster-Wright (2012) concurs that professionals learn from experiences as well as ongoing, active engagement in practices and calls for the support of critical inquiry, which disrupts taken-for-granted discourse in practice.

Further research on math professional development that extends beyond increased content knowledge to how students learn the particular math content in an educational system (Gingsburg, Leinwand, Anstrom & Pollock, 2005) is needed. The research questions for this study seek to gain a better understanding of the combining two models of effective professional development. Experimental research studies employ research questions to determine whether an
independent variable such as a practice or procedure influences an outcome or dependent variable (Cresswell, 2008). Experimental research studies are a required designed element of the Title II B math professional development projects. The use of required elements of the Title II B math partnership projects will contribute to the research base on effective professional development and contribute to the task of increases in teacher content knowledge and teacher pedagogy knowledge.

Intensive and on-going math professional development is needed for teachers of special education classrooms of the regional intermediate unit as well as teachers of diverse students in the local educational agencies within the Lincoln Intermediate Unit 12 service region. The Pennsylvania State System of Assessment (PSSA) student achievement data indicate that the proficiency levels of the super subgroups (i.e., alternative education, deaf/hard of hearing, vision impaired/blind) of the Lincoln Intermediate Unit are less than 15% proficient. Additionally student achievement and student growth data clearly indicate that the White Non-Hispanic group achieves at a higher rate than other subgroups. The Black Non-Hispanic, Economically Disadvantaged and IEP–Special Education subgroups met the standards for adequate yearly progress through alternate calculations (i.e., Safe Harbor, Confidence Interval) or not at all. Additionally not all student groups demonstrate evidence of meeting the PA Standard for Academic Growth on a yearly basis in math. The intermediate unit recognizes that the student achievement results are tied to teacher content knowledge and teacher pedagogy knowledge in instructing mathematics to students with diverse learning needs.

Closing the achievement gap is an issue that extends beyond this particular intermediate unit and the partnering local educational agencies. According to the National Assessment of Educational Progress (NAEP, 2012), the black-white achievement gap in math, for thirteen year
olds was the same amount, 25 points, in 1986, 1994, 1996, and 2012 while the Hispanic-white gap in 1988 was exactly the same as in 2012. NAEP uses a representative sample of the nation’s students and provide results for student groups such as Black, Hispanic, White, and sometimes others, by gender, family income, and school location and school type. Despite the increasing identification of students with disabilities and English Language Learners (ELL) students, NAEP inclusion rates have generally remained steady or increased since 2003. Thus NAEP results reflect students with diverse learning needs. Because nationally there are observable racial and ethnic group gaps in standardized achievement test score and self-reported differences in comprehension of the content and lessons, schools should identify and respond to specific skill and knowledge deficit problems of particular groups (Ferguson, 2002). Ferguson (2002) further suggests that the role of the teacher and the school is to encourage the individual student to meet the demands of academic work by changing classroom practices.

United States teachers participate in short-term professional development similar to counterparts in other nations however there are far fewer opportunities to participate in extended learning opportunities and productive collaborative communities in the United States. The nations that invest heavily in professional learning, building time for ongoing, sustained teacher development and collaboration into teacher work hours consequently outperform the United States on international assessments (Darling-Hammond, Wei, Andree, Richardson, Orphanos, 2009). Enabling educational systems to substantially impact student achievement requires much more intensive and effective professional learning than has been available historically in the U.S. (Hunt, 2009). As a result of expensive, episodic, myopic, and often meaningless professional development, the educational systems of the United States are squandering a significant opportunity to improve teachers’ content knowledge and strengthen professional pedagogies.
The connection between teacher professional development and student achievement seems intuitive however demonstrating the effect is difficult (Yoon, Duncan, Lee, Scarloss, & Shapley, 2007). Yoon, Duncan, Lee, Scarloss, & Shapley (2007) examined 1,300 studies to potentially identify the effect of professional development on student achievement in key content areas (English Language Arts, Science and Math) and only nine meet the What Works Clearinghouse Standards for rigor. Yoon, et. al., (2007) indicate that future studies more fully addressing professional development’s direct effect on teachers and its indirect effect on students would be helpful. The body of research on effective professional development is focused on a deficiency theory as well as a combination of interrelated “factors” (Webster-Wright, 2009). Proclaiming that educators are empty vessels waiting to be filled is not congruent with a notion of professionals as engaged, agentic individuals, capable of self-directed learning (Webster-Wright, 2009). Webster-Wright (2009) calls for a shift in research discourse and focus from increasing professional-development content knowledge to understanding and supporting authentic professional learning. It is widely accepted that learning is dependent on an interaction among the learner, the context, and what is learned (Jarvis & Parker, 2005), yet many professional development research and practice approaches attempt to control or deal with these factors separately. The lack of rigorous research studies (Yoon, et.al, 2007), the need to shift to authentic professional learning (Webster-Wright, 2009), and professional development that is framed upon the interaction among the learner, the context, and the content (Jarvis & Parker, 2005) outline the need for more research on effective professional development.

Positionality Statement

This researcher is in the fourth year of leading professional development at a regional educational service agency that serves both the state department of education and twenty-five
local school districts. The professional development content is either prescribed by the state department of education or specifically created to meet individual school district’s needs. The prevalent method of delivery follows the one-day, teacher in-service workshop model. Some job-alike groups (principals, assistant superintendents, literacy coaches) meet on a regular basis however the meetings are focused on reporting updates from the state department of education rather than professional learning. Personal observations, anecdotal reflections, and exit surveys over the four year period, have led this Professional Development Specialist to question why the intermediate unit continues to perpetuate a model of professional development that conflicts with researched based best practice in professional learning. Additionally previous work experiences leading professional learning communities in a school district, lead this researcher to question how to build ongoing professional development with participants from school districts spread across a tri-county region. Therefore, one of the goals of this researcher is to gain a better understanding of intensive, on-going professional development with participants from multiple educational settings for the benefit of key stakeholders in education: students, teachers, administrators, and community members.

**Research Questions**

The purpose of this study is to assess the impact of intensive, ongoing professional development on teacher content knowledge and teacher pedagogical knowledge. Based on the purpose of this study, the three research questions are as follows:

1. What is the impact of an intensive, on-going professional development on K-8 teachers’ mathematical content knowledge?
2. What is the impact of an intensive, on-going professional development program on K-8 teachers’ pedagogical knowledge?
3. How did teachers of grades K-8 perceive the presence of the core features effective professional development in the intensive, ongoing professional development?

**Theoretical Framework**

The body of research on effective professional development has focused on a theory that is founded on a deficiency model and a combination of interrelated “factors” (Webster-Wright, 2009). Implying a deficiency discourse is not congruent with a notion of professionals as engaged, agency-based individuals; capable of self-directed learning while the value of focusing on learning is congruent. It is widely accepted that learning is dependent on an interaction among the learner, the context, and what is learned (Jarvis & Parker, 2005) yet many research and practice approaches attempt to control or deal with these factors separately. Additionally, relatively recent global changes on education and work have created pressure for ensuring professional standards, measurable outcomes, and accountability of practice (Barnett, 2004; Beckett & Hager, 2002; Fullan, 2003; Giddens, 2002; Hargreaves, 2003) promoting a narrow and dangerous perspective on the value and purpose of professional learning from stakeholders. Research is required that views the learner, the context, and learning as inextricably interrelated (Webster-Wright, 2009).

The Title II B of the Elementary and Secondary Education Act (ESEA) as well as the National Science Foundation’s (NSF) Math and Science partnerships provide nearly two decades of data on effective professional development. Each experimental study had specific guidelines to follow and sought to answer the question: What is the effect of professional development on student achievement? The results reported annually to the federal grant administrators from Title II B ESEA or NSF are the source of seminal professional development authors on math and science partnerships. Garet, Porter, Desimone, Birman, & Yoon (2001), gleaned key learning by
reviewing the results of the over 358 studies involving over 1,027 teachers conducted in the 1997-1998 academic year. The initial report of findings has been cited in over 500 professional works. By using these concepts as models, the consistent and required elements of the math and science partnership professional development program will be intact and allow for the exploration of effective professional development. The effective professional development concepts include the following: 1) Professional development that focuses on academic subject matter such as math and science 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, Porter, Desimone, Birman, & Yoon, 2001); 2) Professional development that is connected to other learning and includes groups of teachers from the same school improves teacher content knowledge, and pedagogy (Garet, Porter, Desimone, Birman, & Yoon, 2001); 3) Additionally sustained and intensive professional development has more impact than shorter professional development (Garet, Porter, Desimone, Birman, & Yoon, 2001); and 4) Tyminski, Ledford, & Hembree (2010) indicate that when teacher educator change is one goal of professional development, devices such as post-program surveys, interviews, or data from participants’ own teaching, selected mathematical tasks and assessment, or classroom observations are utilized to open participants’ practices to discussion and to examination of those practices in a more public way. Merging these concepts into a professional development framework might help leaders of professional development provide effective, efficient, and evidence-based practices that deliver improved outcomes. The framework is illustrated in Figure 1.
This study will examine research to date to determine the effect of intensive, ongoing professional development on teacher content knowledge and teacher pedagogical knowledge.

This chapter offers a critical review of literature relevant to the study of intensive, ongoing professional development and consists of six major components. To better understand the key terms of content knowledge and pedagogical content knowledge, the first section of the literature
review examines the content knowledge for teachers of mathematics. The second section looks at teachers’ pedagogical content knowledge with a focus on a pedagogical content knowledge for teachers of mathematics. The third section of the literature review discusses society’s expectation for effective professional learning. The fourth section addresses the research on the principles of effective professional development. And the fifth component of this chapter describes the historical perspective of professional development to develop teacher knowledge and skills. The evolution of, as well as the principle components of ongoing professional development are described in the final component.

**Teachers’ Mathematical Content Knowledge**

Content, according to Shulman (1986) is the domain of subject area specialists. In this case the domain is mathematics and the subject area specialists are mathematicians. Mathematical content is provided by mathematicians and texts – whether textbooks, worksheets, newspaper articles, film, software programs, and so on (Segall, 2004). Using language and symbol, icon and image, signal and sound, text produces “representations of the world, images, descriptions, explanations and frames for understanding how the world is and why it works as it is said and shown to work” (Alvarado, Gutch, & Wollen, 1987 p.200). Content, according to Shulman (1986) is the domain of scholars, pedagogy the domain of teachers. The fundamental differences between subject matter knowledge necessary for teaching and subject matter per se, were first recognized by Dewey who stated that “[e]very study of subject thus has two aspects: one for the scientist as scientist; the other for the teacher as teacher” (Grossman, Wilson, and Shulman, 1989; Segall, 2004). Grossman, et.al. (1989) claim some of what teachers need to know about their subject overlaps with the knowledge of scholars of the discipline. In the realm of mathematics education, mathematical content knowledge some of what teachers of
mathematics need to know is how their subject area overlaps with the knowledge of mathematicians. Teachers also need to understand math in ways to promote learning to help students acquire knowledge within the subject area of mathematics (Grossman, et. al., 1989).

Shulman (1986) presented the notion that content knowledge needed for teaching also involves knowing “why something is so, not just that it “is” so.” In mathematics this means more than being able to simply compute. This begs the question what content knowledge do teachers of mathematics need to possess? Norman Webb (1997) developed a model to analyze the cognitive demand required to complete curricular activities and assessment tasks. The model, Webb’s Depth of Knowledge (1997), uses the term knowledge to broadly encompass all forms of knowledge (i.e. procedural, declarative, etc....) and can be utilized to classify the cognitive demand required in teacher mathematical content knowledge into 4 levels. Webb’s Depth of Knowledge classifies tasks that require the ability to calculate measure, apply a rule or apply an algorithm as Depth of Knowledge Level 1: Recall & Reproduction. Knowing “why something is so…” aligns with explaining the meaning of a concept and Depth of Knowledge 2: Skills and Concepts. If the task requires the cognitive capability of explaining and supporting the explanation with evidence it would align to Depth of Knowledge Level 3: Short Term Strategic Thinking. Depth of Knowledge 3: Short Term Strategic Thinking is used when explaining and supporting the explanation of the mathematical practice with evidence. Depth of Knowledge 4: Extending Thinking demands higher order thinking processes and conducting investigations to solve real-world problems with unpredictable outcomes. When overlaying Shuman’s (1986) notion knowing “why something is so, not just that it is so” and the translation of this skill in the mathematics world as more than being able to simply compute, Depth of Knowledge Level 2 and Depth of Knowledge 3 can be attributed to the content knowledge teachers need to possess.
To be certified for teaching, many states in the United States require prospective mathematics teachers to pass the Praxis II: Mathematics Content Knowledge (10061) test. The test focuses on measuring their mathematical content knowledge, specifically their undergraduate mathematical knowledge (Wilburne & Long, 2010). In 1990, Ball shared that pre-service teacher understanding of division was based on relatively simplistic and internalized rules and unconnected to other mathematical operations. In other words teacher pre-service content knowledge in division equated to Depth of Knowledge Level 1: Recall & Reproduction. Stoddart, Connell, Stofflet & Peck (1993) concluded that pre-service teachers demonstrated from 37% to 98% accuracy among questions on procedural skills, but only 5% to 10% accuracy with more conceptual based questions. Procedural skills equate to Depth of Knowledge Level 1: Recall & Reproduction while conceptual based cognitive capabilities equates to Depth of Knowledge Level 2: Skills & Concepts. Ball (2003) noted that few mathematics content courses offer opportunities to produce knowledge that is appropriate for elementary school teachers. In addition Mansfield (1985) posits that many secondary pre-service math teachers have gaps in their content knowledge or deficiencies in knowing how to apply and teach the mathematics addressed across the secondary level mathematics courses. In general, mathematics teachers’ subject matter knowledge is not dependent on the number of university courses, their grade point average, or their scores on a standardized test (Even, 1993; Ball, 1990).

Mathematics understanding is described as “the dynamic, constructed, and reconstructed process of sense-making by the learner” and “learning to represent or communicate mathematical ideas or interpret mathematical representations through the use of language, diagrams, pictures, manipulatives, and other tools” (Heaton, 2000, p. 4). Understanding math to this described depth of knowledge equates to Webb’s Depth of Knowledge 3: Short Term Strategic Thinking. When
planning instructional units to support student learning, where students construct and reconstruct mathematics, a teacher is employing cognitive capabilities aligned to Depth of Knowledge 4: Extended Thinking. Usiskin (2001) emphasized the need for pre-service teachers to acquire content knowledge different from the kind they normally receive in college level instruction. Policy documents such as *A Call for Change*, (Lietzel, 1991) and *The Mathematical Education of Teachers* (Conference Board of the Mathematical Sciences, 2001) recommend that the undergraduate preparation of mathematics teachers involve courses that deepen and enhance prospective teachers’ knowledge and conceptual understanding of the mathematics they will teach (Wilburne & Long, 2010). Ball and Wilson (1990) cite the inability of pre-service teachers to understand the meaning behind many mathematical concepts they will be teaching. A predominant theme in the literature on teacher content knowledge indicates that pre-service teachers taking more mathematics content courses may support increased mathematics content knowledge but it may not support the depth of knowledge needed to develop mathematical pedagogical content knowledge. However, there is no consensus in how best to prepare pre-service teachers in order to achieve the important combination of mathematical content knowledge and mathematical pedagogical knowledge (Kirtman, 2008).

**Teachers’ Mathematical Pedagogical Content Knowledge**

Historically in teacher education, a presumption prevailed that pre-service teachers develop subject matter content knowledge and the knowledge of how this content is taught is acquired as a result of training and experience (Foss & Kelinsasser, 1996). Using the example of a study of a 10-week mathematics methods course, Ball (1989) claims “the course experience has impact on the prospective teachers’ ideas but cannot define the extent to which this impact directs continuity of their learning to teach mathematics. Ball (1990) also concluded that pre-
service teachers’ views are likely to shape not only how they teach but also the way they approach learning to teach. Richardson (1994) concurs that without examining foundational beliefs of teaching perceptions, teachers may perpetuate pedagogies based on questionable conceptions. Furthermore, the decision of pre-service teachers to adopt a new methodology is instructionally irrelevant (Richardson, 1994) and may be based on personal beliefs that are unchanged by participation in pre-service training programs (Kagan, 1992). Richardson (1994), Kagan (1992), as well as Brookhart and Freeman (1992) join Ball’s (1988) call for the further examination of the influences of different kinds of teacher education experiences on the participants’ knowledge and orientations toward mathematics as well as the teaching of mathematics. Specifically, the call was originally issued to increase the effectiveness of teacher education (Ball, 1988).

The term pedagogical content knowledge was coined in Lee Shulman’s presidential address to the *American Educational Research Association* (Gess-Newsome & Lederman, 1999). Shulman defined pedagogical content knowledge as a specific form of knowledge for teaching which refers to the transformation of subject matter knowledge in the context of facilitating student understanding and presented the case that teachers need this type of knowledge to structure the content of their lessons, to choose or develop specific representations or analogies, to understand and anticipate particular preconceptions or learning difficulties of their students, and so on… it is the missing paradigm (Shuman, 1986, p. 7).

At the time of the speech, little was known about how teachers deal with such issues and how teachers develop ability in this area (Van Driel, Veal & Janssen, 2001). Since Shulman’s
introduction in the mid-1980s pedagogical content knowledge has done much to further understanding of the relationship between what teachers know, how they come to know it, and as a result how they go about teaching it (Segall, 2004). Research conducted by Grossman (1990), Grossman & Richert (1988), Gudmundsdottir & Shulman (1987), Wilson, Shulman, & Richert (1987), Wilson & Wineburg (1988), Wineburg & Wislon (1988) generated much of that knowledge by those taking part in the “Knowledge Growth in Teaching Project” at Stanford University. The study of pedagogical content knowledge focused on the importance of teachers making content instructional and allowed the concept to become commonly found in the literature in and on teacher education (Segall, 2004). According to Segall (2004) teaching is the transformation of content into pedagogical forms. Content specialists do not possess pedagogical content knowledge which teachers have (or should have); knowledge which, through using a variety of techniques or methods, transforms content per se into content for teaching (Shulman, 1986). Teachers, Shulman (1996) adds, need to find the most useful forms of representation of the [the subject area’s] ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations— in a word, the ways of representing and formulating the subject that make it comprehensible to others (p.9).

Gess-Newsome & Lederman (1999) adopted a broader conceptualization of Pedagogy Content Knowledge that included the components of 1) orientation toward the subject content, 2) knowledge of the subject curricula, 3) knowledge of students’ understanding of the content, 4) knowledge of assessment in science, 5) knowledge of subject-specific and topic-specific strategies may interact in very complex ways. Gess-Newsome & Lederman (1999) also argued...
that “a teaching training program can never completely address all the components of pedagogy content knowledge a teacher needs (p. 982)”.

Confident teachers are comfortable with the content, with designing effective lessons, and teaching the content (Wilburne & Long, 2010). “If American teachers dislike teaching a topic, they may take it upon themselves to eliminate topics altogether from the curriculum or be selective in what and how they teach” (Furner & Robison, 2004, p. 4). The same may be true when teachers lack confidence in their pedagogical content knowledge or the knowledge needed to teach the topic. According to Wilbrne & Long (2010), teachers teach what they are most comfortable with.

Students learn mathematics through the experiences that teachers provide. Thus, students’ understanding of mathematics, their ability to use it to solve problems, and their confidence in, and disposition toward, mathematics are all shaped by the teaching they encounter in school. The improvement of mathematics for all students requires effective mathematics teaching in all classrooms (National Council of Teachers of Mathematics [NCTM], 2000, p. 16-17).

The opportunity to improve the mathematic education of teachers beyond their pre-service preparation exists through professional learning.

**Society’s Expectation for Effective Professional Learning**

In our rapidly changing society, there is a consensus across professions that undergraduate education is only the beginning of professional learning that continues throughout a career (Day, 1999; Graham, 2006; Jarvis, 2004; Knapper & Cropely, 2000; Organisation for Economic Co-operation and Development, 1998b). Across professions, there are increasing
pressures toward the pursuit of more effective, efficient, and evidence-based practices that deliver improved outcomes (Garet, Porter, Desimone, Birman, & Yoon, 2001; Penz & Bassendowski, 2006). Consequently, large quantities of money, resources, time, and effort are expended to research, deliver, and improve professional development practices (Ball & Cohen, 1999; Borko, 2004).

Specifically examining professional learning for educators, Johnston (2011) notes, “there is abundant research indicating that student outcomes in the general population are more closely tied to the quality of teaching than to the characteristics of the instructional program adopted (Darling-Hammond, 2000; Haycock, 2003; Taylor & Person, 2002; Tivnan & Hemphill, 2005).” Additionally, Yoon, Duncan, Lee, Scarloss, & Shapley, K. (2007), found that “teachers who receive substantial professional development—an average of 49 hours in a year–can boost their students’ achievement by approximately 21 percentile points.” Furthermore, “limited professional development—between 5 and 14 hours in total showed a not statistically significant effect on student learning (Jaquith, Mindich, Wei, & Darling-Hammond, 2010, p. 9).” Findings such as these solidify the value of long-term professional development for educators.

Empirical research has demonstrated for over two decades that effective professional learning continues over the long term and is best situated within a community that supports learning (Darling-Hammond, 1997; Garet, et al., 2001; Stoll, Bolam, McMahon, Wallace, & Thomas, 2006; Wenger, 1998). Although there is a need for professional accountability and standards, the definition of professional competence and its standard measurement have been a matter of debate during the past decade with varying perspectives from stakeholders in governments, workplaces, and academia (Beckett, 2004; Darling-Hammond, 1997; Eraut, 2004; Friedman, Durkin, Phillips, & Davis, 2000). Within a performance or accountability framework, the onus shifts toward workers to verify their competence in an observable way (Barnett, 2000;
Usher & Edwards, 1994). The assumption that through continuing learning, professionals will maintain competence and develop expertise is the basis on which much current professional development is predicated.

**Effective Professional Development**

Stein, Smith, & Silver, (1999) point to a significant research base outlining some basic principles for designing professional development that school and district leaders as well as policy makers would be well-advised to consider. First of all, professional development should be intensive, ongoing, and connected to practice. Intensive professional development, especially when presented in context with direct applications of knowledge to teachers’ planning and instruction, has a greater chance of influencing teaching practices and, in turn, leading to gains in student learning (Knapp, 2003; Cohen & Hill, 2001; Desimone, et al., 2002; Garet, et al., 2001; McGill-Franzen, et al., 1999; Supovitz, Mayer & Kahle, 2000; Weiss & Pasley, 2006).

According to results from a national survey, teachers view in-service activities as most effective when they are sustained over time (Garet, et al., 2001). Secondly, professional development should focus on student learning and address the teaching of specific curriculum content. For example, professional development that includes the modeling of classroom practices is more likely to be utilized by teachers (Snow-Renner & Lauer, 2005; Carpenter, 1989; Cohen & Hill, 2001; Garet, et al., 2001; Desimone, et al., 2002; Penuel, Fishman, Yamaguchi, & Gallagher, 2007; Saxe, Gearhart & Nasir, 2001; Supovitz, Mayer & Kahle, 2000). Likewise, teachers judge professional development to be of the greatest value when it provides opportunities to do “hands-on” work that builds their knowledge of academic content and how to teach it to their students, as well as when it takes into account the local context of school resources, curriculum maps, and data systems (Garet, et al., 2001). A third research-based professional development principle supports the alignment of professional learning with school improvement priorities and goals.
Research suggests (Elmore & Burney, 2007; Cohen & Hill, 2001; Garet, et al., 2001; Penuel, Fishman, Yamaguchi & Gallagher, 2007; Supovitz, Mayer & Kahle, 2000), that professional development tends to be more effective when it is an integral part of a larger school reform effort, rather than when activities are isolated, having little to do with other initiatives or changes underway at the school, district, regional, or state level. Professional development, which builds strong working relationship among teachers, is the fourth research-based professional learning principle. Strategically creating time and productive working relationships within academic departments or grade levels, across them or among teachers school-wide, the benefits can include greater consistency in instruction, more willingness to share practices and try new ways of teaching, and more success in solving problems of practice (Hord, 1997; Joyce & Calhoun, 1996; Louis, Marks & Kruse, 1996; McLaughlin & Talber, 2001; Newman & Wehlage, 1997; Successful California Schools, 2007). Researchers have shown many times over the past three decades (Lortie, 1975) that the nation’s teachers exhibit a strongly individualistic ethos, owing largely to the built-in privacy and isolation of their daily work as it has been organized in most U.S. schools. Such cultural norms are not easily changed, particularly if school structures and working conditions continue to favor privacy and isolation. A number of large-scale studies (Bryk, Camburn, & Louis, 1999; Calkins, Guenther, Belfoire, & Lash, 2007; Goddard, Goddard & Tschannen-Moran, 2007; Lois & Marks, 1998; Supovitz & Christman, 2003) have identified specific ways in which professional community building can deepen teachers’ knowledge, build their skills, and improve instruction.

A professional development facilitator from a local education agency, a regional education agency, or a state education agency can accomplish three of the four principles of professional development. It is the fourth principle that is potentially problematic for a local
education agency. Consider situations such as that of a rural high school teacher who is the only teacher of a particular subject within a school district with little or no available options for collaborative professional development. To deepen understanding of how to meet the needs of teachers through a regional professional community, additional research on the culture of relationships within a school as well as current literature on professional learning communities and a reconceptualization of professional development will be considered.

The Historical Perspective of Professional Development

Public schools in the United States were originally organized according to the concepts and principles of scientific management prevalent in the late 1800s (DuFour & Eaker, 1998). Taylor (1915) believed that the principles of scientific management would provide school systems with one best way of delivering effective instruction. In 1934, Cubberley, a superintendent of San Diego schools, declared that public education must follow a bureaucratic system which provides a standardized chain of command in which teachers would follow directives of the administration. This system of bureaucracy provided the backdrop for increased teacher isolation (DuFour & Eaker, 1998). The continued bureaucracy in education led a call for and examination of education in the United States and to the publication of A Nation at Risk. The report, A Nation at Risk cited evidence obtained by the National Commission on Excellence in Education which indicated increased mediocrity in U.S. schools, coupled with evidence that American students were not keeping pace with international peers (U.S. Department of Education, 1983).

Title II, of the Elementary and Secondary Education Act (ESEA) is the federal government’s largest investment that is solely focused on developing the knowledge and skills of classroom teachers (www2.ed.gov). Title II, Part B, also known as the Eisenhower program,
with a 1999 appropriation of about $335 million, is a source of funding for professional
development activities that are wide-ranging and include workshops and conferences, study
groups, professional networks and collaboratives, task force work, and peer coaching. Title II
Eisenhower funding is channeled through state educational agencies to school districts, and
through state agencies for higher education to grantees. Grantees can include institutions of
higher education such as universities, 4-year colleges, or 2-year colleges and not-for-profits to
support professional development in mathematics and science. Title II funding does not exist in a
vacuum, professional development activities funded by the Eisenhower program may also
receive funding through states, school districts or other federal programs. Garret et al. (2001)
note that the study of the effects of the Eisenhower assisted professional development activities
on teacher outcomes is also applicable to professional development funded through other
sources. Grantees are required to report outcomes to the granting agency.

The American Institutes for Research under contract with the U.S. Department of
Education’s Planning and Evaluation Service, conducted multi-year evaluations of the
Eisenhower Professional Development Program which examine the relationship between
features of professional development and self-reported change in teachers’ knowledge and skill
and classroom teaching practices (Garret et al., 2001). A 1997 longitudinal study with a national
sample which, included 93% of districts in the country, surveyed 1,027 teachers and built upon
the research premise of Garet et al., (2001). Desimone et al., (2002) concluded that the key
features of professional development (i.e. reform type, duration, collective participation, active
learning, coherence and content focus), could be hypothesized as effective and were related to
increases in teachers’ self-reported knowledge and skills and changes in teacher practice.
Furthermore based on the national teacher self-reported data gathered on the prevalence of the
six characteristics and teacher perception of the effect on their knowledge, skills, and classroom practices it was found that most district supported professional development activities do not have the six high-quality characteristics (Desimone et al., 2002). Results of the national survey indicated that only 23% of teachers participating in Eisenhower-assisted professional development activities were in reform types of professional development and the average time span of professional development was less than a week. Most activities did not have collective participation or a major emphasis on content. The average number of contact hours was 25 and only a small number had active learning opportunities (Garet et al., 2001).

The longitudinal data indicate that professional development is more effective in changing teacher practice when teachers from the same school, department, or grade collectively focus on active learning opportunities, such as reviewing student work or obtaining feedback on teaching, that are linked to other activities or build on previous knowledge (Desimone, et al., 2002). Desimone, et al. (2002), also concluded that reform type professional that focus on a set of higher order instructional or alternative assessment methods had a positive effect on changing teachers’ classroom practice however, no effects for duration were found. The national data also document great variation in the quality of teachers’ professional development activities as districts resources necessitate choosing between higher quality professional development for fewer teachers or less focused and sustained professional development for larger numbers of teachers (Desimone, et al., 2002).

Fulton, Yon and Lee (2005) acknowledged that the current factory model school is in fact grossly inefficient, inappropriate, and ultimately inequitable, requiring all children to adapt to the mean. “Those who do not learn at the speed of the assembly line lose out and/or drop out: those who could learn more do not. Individualizing instruction for each learner is no longer a dream—it
is an educational birthright for all children” (Fulton, 2003, p. 32). In comparison, the factory model of professional development relies heavily on the classic teacher in-service days with experts leading one-shot infusions of new ideas to large groups of teachers on broad topics (i.e. differentiated instruction, diversity, positive behavior management, technology integration) or they might focus on product implementation of corporate-created curricula (Hinchey & Cadiero-Kaplan, 2005). Many educational agency initiatives are fragmented, top-down, and embody, according to Fullan and Hargreaves, “a passive view of the teacher, who is empty, deficient, lacking in skills, needing to be filled up and fixed with new techniques and strategies” (1996, p.17). Desimone, et al., (2002) concur that “schools generally do not have a coherent, coordinated approach to professional development and instruction, at least not an approach that is effective in building consistency among their teachers” (Desimone, et al., 2002, p. 105). Furthermore participation in professional development is largely an individual teacher’s decision and teachers often choose professional learning from a number of options available provided by dissimilar providers (Skyes, 1996). With a highly disparate set of professional development providers, much of the variation in professional development and teaching practice is between individual teachers within schools, rather than between schools (Desimone, et al., 2002).

Influential professional and government organization, such as the American Educational Research Association and the U.S. Department of Education catapulted a philosophical shift in professional development (Resnick, 2005) which recognized the need for systemic professional development to develop teacher content knowledge (the subject matter that teachers will be teaching) and pedagogical content knowledge (how students learn particular subject matter) (Kesson & Henderson, 2010). The educational reform movement brought about by the No Child Left Behind Act (2000) also brought a demand for teachers to be immersed in the subjects they
teach, have the ability both to communicate basic knowledge, and to develop advanced thinking and problem-solving skills among their students (Loucks-Horsley, Hewson, Love, & Stiles, 1998; National Commission on Teaching and America’s Future, 1996). The essential elements of systemic reform—develop curriculum frameworks and sophisticated units, learn new instructional methods to teaching challenging content, develop capacity to teach to differentiate instruction to match student learning styles, gain competency with data directed instruction, and create learning communities for refinement of instructional practices (Cohen, 1990; Elmore & Burney, 1996; Elmore, Peterson, & McCarthey, 1996; Grant, Peterson, & Shojgreen-Downer, 1996; Sizer, 1992; Kesson & Henderson, 2010).

Around the same time Cubberley promoted a bureaucratic system, Dewey celebrated the power of new ideas, insightful critique and continuous inquiry that challenged the ideological and institutional “regimes of truth.” According to Dewey (1999/1929, p. 76) “if dogmas and institutions tremble when a new idea appears, this shiver is nothing to what would happen if the idea were armed with the means for the continuous discovery of new thought and the criticism of old belief.” Dewey’s call for “continuous discovery of truth” mirrors Fullan’s (1991) call for the redesign of the educational workplace to include daily activities where educators manipulate information to encourage innovations and improvement of their craft.

Newman & Wehlage (1995) identified the practice of organizing information for interpretation and consideration of alternatives as a standard of authentic pedagogical practice. In their seminal study, of student learning in more than 24 significantly restructured schools, sampling over 10,000 students from grades eight through twelve, Newman & Wehlage (1995) concluded that education reform measures often place too much emphasis on school restructuring practices which do not directly address the issue of student learning. Additionally,
through the use of content, process, and written communication, learners used the information provided to create and better understand concepts practiced. Senge (1990) posits that organizations desiring positive and effective change must focus on collaborative and continuous learning. Handy (1995) supported the notion that individuals within organizations will increase success rates when permitted to learn from failures. The process of questioning the status quo is more important than having an answer (Senge, Kleiner, Roberts, Ross & Smith, 1994) and collective inquiry drives improvement, growth, and renewal among educators.

Essential to the success of high-achieving schools is a collaborative focus on teaching and learning deeply embedded in the culture of the organization (Barth, 2001; Hipp & Huffman, 2003). Another attribute is the creation of collaborative teaming in which educators work toward collective learning (DuFour & Eaker, 1998). Collaborative learning promotes the growth of the organization rather than the individual educator. Collins (2001) found that successful transformation of organizations from good to great was a cumulative process of persistence and focus on a central goal over an extended period of time. In Hargreaves’ (2004) words, “A Professional Learning Community is an ethos that infuses every single aspect of a school’s operation” (p. 5). The professional learning community is a collegial group of administrators and teachers who are united in the commitment to student learning, share a vision, work and learn collaboratively, visit and review each other’s classrooms, and participate in decision making (Black, 2007; Hord, 1997). Eacker, DuFour, and Burnette (2002) suggested that communities of learners build productive relationships necessary for collaboration, partnerships, reflection and implementations of school improvement programs.

The Research on Ongoing Professional Development

Barth (2006) defines adult relationships within schools in four ways: parallel play,
adversarial, congenial and collegial. Improving instructional practice means moving from working in isolation, competing with our peers, and beyond friendship toward creating a culture of collegiality. Specifically, the lowest level of adult relationship is parallel play and is described by Barth (2006) as similar to the play of preschool children who are in the same proximity yet never interact, remaining in isolation from their peers. Parallel play also can occur among adults when colleagues work in isolation in their classroom. The term equally extends to principals whose schools are only blocks away, yet they work independently in their corresponding roles. Parallel play conceals professional practice from our colleagues who might cause us to question and improve those practices.

Adversarial relationships, another adult relationship found in schools, take many forms including blatant, withholding and competitive. When a teacher says to parents, “Oh, you don’t want your child in that classroom,” it is like a metaphorical sword blatantly stabbing the colleague across the hallway. Rather than engage in warfare, it is easier to hide behind classroom doors in parallel play mode. Most educators engage in adversarial relationship in a more subtle way— withholding insights, and ideas about the craft of teaching. Educators are reluctant to share teaching practices and beliefs for fear of losing their uniqueness or facing peer rejection. In schools, teachers are so competitive that they hold onto their treasured ideas, consider it stealing when a colleague copies their idea or feel inadequate for not thinking of that idea first. (Barth, 2006)

Congeniality is easier to find in schools than collegiality. Such relationships are personal, friendly, and often are centered around food. Congenial relationships are what get us up and off to school each morning. They are important as they represent a precondition for the highly-prized, yet elusive collegiality. (Barth, 2006) Of the four categories, Barth (2006)
indicates that collegial relationships are the hardest to establish as educators have to play together and grow a professional learning community. Signs that a school has moved to collegiality among teachers and administrators include educators talking with one another, sharing their craft knowledge, observing one another, and rooting for one another’s success. (Barth 2006).

Identifying cultural barriers such as established norms, attitudes, beliefs, behaviors, values, ceremonies, traditions, and myths that are deeply ingrained in the very core of the organization that schools need to overcome to support good professional development is the first step in changing the school’s culture. Fullan (2002), found a starting point of cultural change to be in the belief in the importance of “teachers as learners,” and the understanding that improving practice by acquiring new knowledge and skills is a professional obligation. Fullan (2002) further clarifies this as a belief that the work of becoming a great teacher is a life-long endeavor. Professional development is a prime opportunity to encourage teacher learning in the 21st century skills of collaboration & problem solving.

According to Chappuis, Chappuis & Stiggins (2009) teachers are accustomed to staff development or professional learning where the presenter has all the responsibility for action and the participants’ responsibility is limited to being physically present. To progress toward a collegial professional development model, the understanding that professional development can be a team experience that involves all participants, focuses learning on a specific topic and strengthens classroom practice is needed. (Chappuis et al., 2009) For example, learning is brought to the team through an expert, by reading books or articles, or viewing footage of classroom practice. This information is transferred to the teachers’ context by preparing lessons, materials, and activities to use with students. Participants then observe, reflect on the results, as
well as discuss, problem solve, and create. As teachers share what they have learned, what they tried, observed, and what happened with students in an environment that sets the expectations for the team to come prepared, remain focused on helping students, participate, and stay on topic they begin to grow into a collegial community of learners (Chappuis, et. al., 2009).

Darling-Hammond & Richardson (2009) state when whole grade levels, schools or departments are involved, they create a critical mass for changed instruction at the school level. Additionally, teachers serve as support groups for one another in improving practice. Collective work in a trusting environment provides a basis for inquiry, reflections, allowing teachers to raise issues, take risks, and address dilemmas in their own practice. Darling-Hammond (1996) describes sustained, job-embedded, collaborative teacher learning strategies as professional learning communities.

Other school reform experts define a professional learning community differently. For example Hord (1997) describes it as an ongoing process through which teachers and administrators work collaboratively to seek, share, and act on their learning, their goal being to enhance their effectiveness as professionals for students’ benefit. DuFour, (2004) explains a professional learning community as educators committed to working collaboratively in ongoing processes of collective inquiry and action research to achieve better results for the students they serve. Feger & Arruda (2008) view a professional learning community as a strategy to increase student achievement by creating a collaborative school culture focused on learning. As a professional learning community is not a prescription, a new program, a model, or an innovation to be implemented, it is difficult to define.

As a result of such varied yet similar descriptions it is easy to understand how Schmoker (2004) argues that true professional learning communities though simple, proven, and affordable
structures are still extremely rare. DuFour (2004) cautions that the term professional learning communities is being incorrectly extended to traditional educational meetings and encourages educators to reflect upon the big ideas representing the core principles of professional learning communities to prevent the progress toward collegiality from overuse and eventual demise. The core principles include ensuring that student learning is the core mission of education, responding with timely, directive intervention when a student experiences difficulty, building a culture of collaboration around a systemic, on-going process of deep learning, and improvement in classroom practice. Employing the core principles of effective professional development leads to higher levels of student achievement.

Summary

The research on effective professional development is extensive and points to a model that continues over the long term, is related to professionals’ work and is situated with a community of learners. Professional learning that is focused on student learning and addresses the teaching of specific curriculum content is more likely to be utilized by teachers. Teachers value professional development when it provides “hands-on” opportunities to build teacher content knowledge of academic content and how to teach their students. Professional development that is aligned to school improvement goals, school resources, curriculum maps and data systems is more effective than learning that is disconnected to school reform efforts or changes in progress at the school, district, or state level. Building productive working relationships among colleagues teaching the same content or grade-level can improve consistency of instruction, sharing of practices, and collaborative problem solving. However, the professional support and training teachers from the United States receive continues to be episodic and disconnected from their work. Local educational agencies have not changed their
teacher in-service practices to align with research-based best practices of effective professional development. Teacher in-service days are devoted to compliance with state department of education mandates, broad district-wide education goals, or general education topics that apply to the majority of the district instructional staff.

The Math and Science Partnership projects under Title II B of the Elementary and Secondary Education Act, serve as the basis of seminal research on effective professional development. In recent years The Math and Science Partnership project have shifted in to add 24 hours of ongoing professional development to the previously required eighty hours of intensive professional development. In terms of the Math and Science Partnership projects the concept of intensive professional development equates to a two-week summer course focused on broad categories of either Math or Science content (i.e. STEM). The additional 24 hours of ongoing professional development is broken into 3 or 4 additional meeting dates over the course of an academic year.

Professional learning communities could also be categorized as intensive, ongoing professional development. In a professional learning community learning is brought to the team by reading a common text, viewing videos of classroom practice, or analyzing achievement test data. Collegial professional development is a team approach where all participants take responsibility for learning a specific topic, remaining focused on student achievement and staying on topic. Professional learning communities are also defined as a collective inquiry and action research to increase student achievement. Without a prescription, model, program or innovation, a professional learning community is difficult to define. Neither the research gleaned from the Math and Science Partnership project nor professional learning communities focuses on specific content knowledge development. In K-8 mathematics specific content
knowledge might focus on Geometry, Algebraic Concepts or Numbers and Operations, all of which are major strands of K-8 mathematics course content. A research base of intensive, as in focused on specific content knowledge and related pedagogical knowledge, paired with ongoing professional development is needed to explore the effect of combining intensive and ongoing professional development.

Chapter III: Research Design

Methodology

The purpose of this outcome evaluation study was to determine the impact of an intensive, ongoing professional development program focused on the development of teacher content knowledge, pedagogical knowledge, as well as their perception of the presence of core features of the program. Outcome evaluation studies are grounded in a program’s theory of change and are well suited for program evaluation (Penna & Phillips, 2005). Following the framework for effective professional development the design of the program focused on the development of teachers’ content knowledge, active learning, coherence, public examination of practice and enhanced knowledge and skill. The development of teachers’ knowledge and skills was measured with a mix of qualitative and quantitative assessments. Cresswell explains quantitative data, such as scores on an assessment, generates “specific numbers that can be statistically analyzed, can produce results to assess the frequency and magnitude of trends…” while “…qualitative data, such as open-ended interviews that provide actual words of the people in the study, offer many different perspectives on the study topic provide a complex picture of the situation” (2012, p. 535). By assessing the quantitative outcomes of a study and qualitative processes the researcher can create a “very powerful mix” (Miles & Huberman, 1994, p. 42) and can develop “a complex picture of social phenomenon” (Green & Caracelli, 1997, p. 7). The
intertwining of quantitative and qualitative measures in an outcome evaluation study can provide a better understanding of the research problem and question than either method exclusively (Cresswell, 2012). Since this study involved teachers engaged in an intensive, on-going professional development program in order to increase their content knowledge and pedagogical knowledge using core features identified as effective professional development, an outcome evaluation study utilizing both quantitative and qualitative data to examine the research questions was employed.

According to Cresswell (2012), an input influences an outcome. An outcome of the teachers’ participations in an intensive, ongoing professional development program with a focus on content knowledge, active learning, coherence and public examination of practices was intended to influence teachers’ content knowledge and pedagogical knowledge. Employing core features of identified effective professional development were intended to - produce some outcomes that can be measured with a pre- and post-test instrument. According to Cresswell (2012) a pre-test provides a measure on some attribute or characteristic that is assessed prior to participants’ experience of the program and a post-test would be able to determine changes in those attributes. A pre-test and post-test instrument in the mathematical domain of Whole Numbers and Computation, developed by the University of Louisville Center for Research in Mathematics and Science Teacher Development (2004), was administered to participants in the intensive, ongoing professional development program. The 20 item pre-test and 20 item post-test were composed of 10 multiple choice and 10 open responses to determine teacher knowledge growth over time as well as the effects of this particular experience on teacher’s knowledge or relationships among teacher content knowledge, and teacher pedagogical knowledge. The Diagnostic Mathematics Assessments for Elementary and Middle School Teachers pre-test and
post-test were used to measure the impact of the professional development program on teachers’ content knowledge and pedagogical knowledge (Figure 1).

*Each Structural Features flows into each Core Feature.*

**Figure 1.** Framework for Effective Professional Development

The purpose of this study was also to investigate teachers’ perception of the presence of the particular features the professional development program in keeping with features identified with effective professional development. An end of program questionnaire was voluntarily completed by half of the participants on the last day of the program. The questionnaire consisted of eight items and included four close response questions rating the presence of elements of effective professional development in the program and four open response questions. According to Cresswell (2012) surveys consist mainly of closed-ended questions in which the researcher provides a predetermined set of response options. This allows the researcher to conveniently compare responses. Close-ended questions also provide a means for coding responses or assigning a numeric value and statistically analyzing the data producing quantitative outcomes.
To probe deeper and explore the many possibilities individuals can create for a question, and allow participants to create responses within their cultural and social experiences researchers do not provide response options for open-ended questions (Neuman, 2000). Open response questions generate qualitative outcomes to enhance the understanding to the research questions. Tyminiski, Ledford, & Hembree (2010) indicate that when teacher educator change is the one goal of professional development, devices such as post-program surveys, interviews, or data from participants’ own teaching, selected mathematical tasks and assessments or classroom observations are used to open participants’ practices to discussion and examination of those practices in a more public way. Gathering participants’ perceptions of the presence of the core features of a program can benefit the program developers. In this case, features of the program included: (1) a focus on teachers’ mathematical content knowledge; (2) active learning (for example, through whole group discussion, small group discussion and math manipulatives participants were invited to extended the opportunity to engage in the learning community); (3) coherence (for example weekly homework assignments required the integration of the content knowledge and pedagogical knowledge into to daily teaching routines; and 4) public examination of practice (for example whole group and small group discussion). The open-ended question responses bring voice to the participants’ perceptions of the presence of the four core features of effective professional development.

The professional development provider through an end of program evaluation gathered additional perceptual data. The end of program evaluation asked eight questions regarding perceived outcomes of the intensive, ongoing professional development. For three items (see Figure 2), participants indicated, with an X on a line, perceived professional development along three continua. The placement of the X represented what portion of the professional growth was
content knowledge compared to pedagogical knowledge. The Xs on the continua were quantified by measuring the location of the mark, a range from 0 to 10 centimeters. Four questions on the end of program evaluation asked participants to rank the instructor’s facilitation of the workshop on a scale of 1 to 4, generating additional quantitative data (see Table 1). And the last section of the end of course evaluation included two open-ended response questions for participants to generate qualitative data on the participant perception of the program.

![Image of continua diagram]

**Figure 2.** End of Program Evaluation Perceived Professional Development Continua

Intertwining the qualitative data of participant perception with the quantitative data of participant perception as well as the quantitative data of content knowledge and pedagogical content knowledge established a deeper understanding of the program. The “powerful mix” of open response questions, close response questions and selected mathematical assessment tasks were employed to measure the outcomes of enhanced knowledge and skill as a result of participation in intensive, ongoing professional development program which utilized the core features of identified effective professional development.

Table 1

*End of Program Evaluation Rating Instructor’s Facilitation*

<table>
<thead>
<tr>
<th>Rating: 1-Lowest to 4-Highest</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Question 1: How much impact did the workshop have on your professional growth?</td>
<td>0</td>
<td>5</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>Question 2: How well did the instructor maintain a professional climate that promoted learning?</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>16</td>
</tr>
<tr>
<td>Question 3: How likely are you to recommend future workshops facilitated by this instructor to a colleague?</td>
<td>0</td>
<td>1</td>
<td>5</td>
<td>11</td>
</tr>
<tr>
<td>Question 4: How well did the instructor facilitate your understanding of the material in this workshop?</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>12</td>
</tr>
</tbody>
</table>

**Study Context**

In Pennsylvania, intermediate units are regional educational service agencies established by the Pennsylvania General Assembly as part of the governance structure of public education. Intermediate units are located in the middle between the state education agency and the local school districts to provide specialized services, such as professional development, that can be operated more effectively and efficiently on a regional basis. Professional development was routinely held for educators working in schools located within an intermediate unit’s regional service area. One intermediate unit in South Central Pennsylvania was the research site for the study. The Lincoln Intermediate Unit was the research site for the study because of the availability of potential participants, i.e. teachers that have volunteered to participate in the intensive, on-going professional development. The Lincoln Intermediate Unit (LIU) formed a Math and Science Partnership, with local educational agencies to offer professional development to their teachers of grades K-8 math. Included in the local educational agencies is CASD, the 22nd largest school district in the state covering 250 square miles. The district employs 340 teachers who provide instruction to 6,015 students in grades K-8. The RLASD was a similar
combination rural and suburban local education agency (LEA) that covers 142 square miles. Math and science instruction was provided to 3,690 students, in grades K-8 by 157 RLASD teachers. Nearly all of the local educational agencies in the Lincoln Intermediate Unit service region have changed in recent years to reflect a large increase in subgroups not previously represented in the districts. Specifically the economically disadvantaged, Black-nonHispanic, and Latino/Hispanic sub-groups have increased in the districts. Accordingly adjustments to instruction have been made yet the goal of all student groups meeting adequate yearly progress measures has not been attained (PAAYP, 2013).

Previous large-scale efforts to provide consistent and pervasive professional development in math content knowledge and teacher pedagogy in mathematics had not occurred previously in the participating LEAs. RLASD, like the majority of participating LEAs, did not offered in-depth instruction in Mathematics beyond text-book orientation (Wilson, 2013).—According to Knepper (2013), over the past three years the CASD provided a variety of professional development opportunities in grades K-8. Voluntary math professional development was offered to elementary teachers on topics from inquiry-based learning to incorporating writing in the math classrooms. Mandatory professional development was provided to 3rd grade teachers on the Common Core Math Standards, standards based reports cards, and an "Investigations" math program. Middle School teachers were trained in Power Teaching, Writing in the Math Classroom and the Common Core State Math Standards. Despite a range of professional development opportunities available, local educational agencies have not offered rigorous, systematic, and pervasive professional development.

The LIU employs teachers of students with diverse learning needs. Teachers in the alternative education programs housed at LIU facilities and neurological support classrooms
housed in various local educational agencies facilities within the intermediate unit’s region were also invited to participate in the intensive, on-going professional development. The Director of Special Education and supervisors of the respective special education programs agree that no specific professional development in key content areas was offered to the instructional staff (Bertram, 2013).

A Professional Development Needs Assessment was distributed electronically to the teachers of the intermediate unit special education classrooms, the CASD mathematics teachers and the RLASD mathematics teachers who instruct students in grades K-8. Teachers who completed the Professional Development Needs Assessment were considered the population from which the experimental group will be solicited. Teachers who registered for the ten-week intensive, ongoing professional development workshop series served as the intervention group.

Assurances from all participating LEAs were obtained for all assessments and trainings to be administered in accord with the proposed study design as well as for the provision of annual data on school-level measures that will be used for the evaluation. All treatment and control participants were clearly informed of their roles and responsibilities in the evaluation data collection for the life of the project regardless of whether they continue to work in the participating LEA’s if appropriate. The Lincoln Intermediate Unit’s governing body ensured compliance with Federal Human Subjects Protection regulations as well as the participating LEA’s IRB requirements.

Participants

This study specifically focused on teachers of mathematics from the regional service area of one intermediate unit. Essential data from pre-tests, post-tests, and surveys were collected from seventeen teachers of mathematics participating in an Inspired Math Teacher: Numbers &
Operations, ten week professional development series. The math teachers in this study provided instruction to students in grades kindergarten through eight. One participant in this study was a middle school principal who intended to share the content with his instructional staff. The participants’ teaching assignments ranged from kindergarten through grade eight (Table 2). One participant taught kindergarten, another was assigned to fifth grade and a third participant taught grade seven mathematics. Three participants taught sixth grade level math. Ten of the participants had teaching assignments that spanned multiple grade levels. Two teachers were assigned to teach in each of the following categories, math coaches, math interventionists, English as a Second Language (ESL), Special Education and Middle Level Math (grade 6-8). In those teaching assignments participants instruct small groups of students from with-in a grade level band such as kindergarten through grade three or kindergarten through grade five or even math for grades six through eight.

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Participants’ Teaching Assignment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>K 5 6 7 6-8 Coach Intervention ESL Special Ed</td>
</tr>
<tr>
<td>1</td>
<td>1 1 3 1 2 2 3 1 2</td>
</tr>
</tbody>
</table>

All of the participants were certified to teach Elementary Education or Secondary Education in Pennsylvania. One participant held an administrative certificate and was the principal of a middle school (Table 3). The sixteen remaining participants were certified in Elementary Education or Special Education. Nine participants hold elementary certificates and two were certified in special education. Six participants were dual certified, two of those in
elementary education and special education. Four additional participants held an elementary certificate with a middle school level math endorsement.

Table 3

*Participants’ Certification Area*

<table>
<thead>
<tr>
<th>Area</th>
<th>Elementary</th>
<th>Administrator</th>
<th>Sp Ed</th>
<th>Elem &amp; Sp Ed</th>
<th>El &amp; MS level math</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>9</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 4 shows participants’ teaching experience and gender. The participants of this study ranged in experience from 1 year to thirty-one years of experience (Table 4). One participating was in their very first year of teaching. Two teachers had over 24 years of experience. The participant with the most experience had completed 31 years of teaching. The experience of the remaining participants fell between six years and 20 years. All of the participants were female with the exception of one.

Table 4

*Participants’ Experience & Gender*

<table>
<thead>
<tr>
<th>Years</th>
<th>1 -5 years</th>
<th>6 – 10 years</th>
<th>11 – 15 years</th>
<th>16 – 20 years</th>
<th>21+ years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>1</td>
<td>5</td>
<td>3</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Male</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

An elementary teaching certificate was required to teach in grades kindergarten through grade six. Some middle schools in Pennsylvania include grade five and six. To be certified to teach in the elementary grades, the Pennsylvania Department of Education required pre-service candidates to complete three mathematics courses. Middle level mathematics certification in Pennsylvania required more than three college courses in mathematics. Table 5 shows the
number of college math courses completed by participants prior to starting the ten-week, intensive ongoing professional development program. Nine out of the seventeen participants completed between zero and three college courses prior to the start of the professional development. Five participants completed between four and six courses and three participants completed between seven and nine courses.

Table 5

Number of College Math Courses Completed

<table>
<thead>
<tr>
<th>Courses</th>
<th>0-3</th>
<th>4-6</th>
<th>7-9</th>
<th>10-11</th>
<th>&gt;12</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>9</td>
<td>5</td>
<td>3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Design

The intent of this study design was two-fold: (1) for the Lincoln Intermediate Unit professional development specialist to gain experience in carrying out large scale professional development projects; and (2) to measure the impact of intensive, ongoing professional development mathematics on teacher content and pedagogical knowledge, and to collect and review teachers’ perceptions of the presence of core features in the intensive, ongoing professional development program. As such this study was modeled after the Math and Science Partnership Professional Development projects funded through Title II B of the Elementary and Secondary Education Act. Required assessment tools in the MSP projects included a professional development needs assessment and the Diagnostic Mathematics Assessment for Elementary and Secondary Teachers and were used in the study design. The Pennsylvania State System of Assessment results, post course evaluations and focus group questionnaires were not
among the required Math and Science Partnership data collection tools but were utilized in the study design so that multiple measures of data are analyzed.

**Professional Development Needs Assessment**

A professional development needs assessment developed by Wilson (2012) (Appendix A) was administered to determine the content focus in the intensive, ongoing professional development. Teachers of mathematics from RLASD, CASD and the Lincoln Intermediate Unit voluntarily completed the assessment in the spring of 2013 prior to recruitment for participation in the intervention. The Professional Development Needs Assessment was a closed response tool that is differentiated by teaching assignment. After denoting which grade level they were assigned to teach, the teacher was directed to the portion of the tool corresponding to the mathematical content taught at that grade level. By specific grade level, check boxes were provided in the strands of mathematics the Pennsylvania Department of Education expected to be mastered at that grade level. For examples strands at the fifth grade include Numbers & Operations, Measurement, Data Analysis & Probability, Geometry and Algebraic Concepts. Within each strand the teacher then selected topic(s) they wished to have included in future professional development. The topics included in the assessment also align to the expectations of the Pennsylvania Department of Education by grade level. Completion of the survey required participating teachers to answer two items about grade level assignment and accommodations. After the two required items, the number of options for professional development a teacher could choose from ranged from 11-12. Thirty-five teachers completed the professional development needs assessment to provide direction to the researcher for mathematical content to include in the intensive, ongoing professional development.

**Pennsylvania State System of Assessment**
In addition to the results of the Professional Development Needs Assessment, the student results of the Pennsylvania State System of Assessment were examined to provide direction to the researcher for the mathematical content to be included in the intensive, ongoing professional development. The Pennsylvania Department of Education in conjunction with Data Recognition Corporation developed the Pennsylvania State System of Assessment (PSSA). The PSSA measured student achievement in math, reading, science, and writing via multiple choice and constructed response tests aligned to the Pennsylvania Academic Standards, Assessment Anchors, and Eligible Content. The PSSA was administered as a summative assessment annually to Pennsylvania students in grades 3-8 in the areas of reading and mathematics. Pennsylvania students in grades 4 and 8 also completed a PSSA assessment in science. Students in grades 5 and 8 completed a PSSA Writing assessment. The PSSA was administered in either an online or paper format. Multiple versions of the tests were distributed to students in a particular grade. Each version of the test had items from a pool of items as well as field test items. The field test items were used to collect data on potential new test items and were not counted in a student achievement scores. Multiple-choice items were machine scored while teams of Pennsylvania educators scored constructed response items. Results of the PSSA were reported as scaled scores and assigned an achievement level. The results were also attributed to a reporting category. In the case of mathematics the categories were numbers & operations, geometry, data analysis & probability, measurement, or algebraic concepts. Below is a sample of a 5th grade mathematics question (Figure 3).
The Pennsylvania State System of Assessment (PSSA) exhibited strong convergent validity coefficients. Correlations were very high between PSSA and Student Aptitude Test (SAT). The PSSA was positively correlated with other measures of student achievement including course grades and grade point average (GPA). Gains on PSSA were reflective of changes on the SAT at the school level. All these data provide strong evidence in support of PSSA as a valid measure of student achievement (Human Resources Research Organization, 2004).

The Mathematics PSSA in grades 3-8 was used to measure student achievement as related to the input of focus on content knowledge. As the primary purpose of the PSSA was to determine student achievement level of individual students, the PSSA mathematics assessment was a logical and appropriate instrument to measure the mathematics professional development.
content that would be of value to the study participants and ultimately their students. By comparing the measure of achievement of the participating LEAs with the professional development needs assessment results the content (i.e. Numbers and Operations, Algebraic Concepts, Geometry or Measurement) of potential value to the participants was determined.

The PSSA test scores were accessible to the public on the Pennsylvania School Performance Profile. This data was reported at the building and district level. The PSSA results from the 2013 mathematics assessment were gathered from the website. Data Recognition Corporation, the assessment contractor retained by the Pennsylvania Department of Education to produce and score the PSSA, reported high reliability coefficients of greater than 0.9 for PSSA reading and mathematics tests (HmRRO, 2004). Additionally, the PSSA had high internal consistency reliability estimates due, in part, to the large number of items on each test (HmRRO, 2004). Convergent validity coefficients were about the same from year to year (HmRRO, 2004). At both the student level and the school level, the different assessments of mathematics achievement were more highly related to each other than to assessments of other subjects. Students with high mathematics scores on one assessment tended to do well on all other assessments, but that tendency was most pronounced for other mathematics assessments. The same held true for school scores. There was a similar differentiation on reading/verbal assessments at both the student and school level, but not as pronounced as in mathematics. Gender, race, socioeconomic status, nor limited English proficiency appeared to influence the PSSA scores any more than would be expected based on observed differences for Scholastic Aptitude Test (SAT) scores. In other words, PSSA items were not injecting any unexpected gender, racial/ethnic, socioeconomic status, or limited English proficiency bias thus reduced threats to validity.
Other threats to validity were minimalized through multiple school locations, test administration protocols, and implementation of the treatment. The internal threat of location was controlled as the students were in multiple classrooms, in multiple school buildings. The threat of instrument decay was reduced, as there were strict protocols for PSSA test administration to ensure test security. All building administrators, as well as PSSA test administrators/teachers attended an annual PSSA test administration training to ensure adherence to protocols. The same professional development provider delivered the training materials simultaneously to the intervention group to control the implementation threat.

**Recruitment of Participants**

Electronic communications were distributed between the Division of Educational Services of the Lincoln Intermediate Unit and the participating LEAs to recruit volunteer participants. Specifically, an email (Figure 4) with an informational flyer (Figure 5) and registration details was sent to district and building level administrators. The administrators forwarded the communication to instructional staff as they deemed appropriate. Eighteen participants registered to attend the 10 week on-going, intensive professional development and seventeen attended.

![Figure 4. Professional Development Marketing Email](image-url)
Data Collection

For the purpose of this study, multiple measures of data were collected so the outcome of enhanced knowledge and skill was analyzed (Bernhardt, 1998). The multiple measures included an end of program questionnaire; a pretest; a posttest; an end of program evaluation; a professional development needs assessment; and results of the Pennsylvania State System of Assessment. The professional development needs assessment was administered to teachers of K-8 mathematics from participating LEAs with the knowledge their responses influenced future professional development opportunities. Collection of pre-test and post-test scores yielded data to address each of the research questions. Additional measures are described below, delineated
by research questions. Beyond the Math and Science Partnership required data collection, teacher perceptual data and demographic information were collected through end of program evaluations and questionnaires. An external scoring service and external professional development provider were employed to ensure fidelity of all evaluations. Assurances from all participating LEAs were obtained for all assessments and trainings to be administered in accord with the proposed study design. All participants were clearly informed of their roles and responsibilities in evaluation data collection for the life of the project regardless of whether they continue to work in the participating LEA, if appropriate. The Lincoln Intermediate Unit’s governing body ensured compliance with Federal Human Subjects Protection regulations as well as the participating LEAs’ IRB.

**Instruments**

**Diagnostic mathematics assessments for elementary/middle school.** The Diagnostic Mathematics Assessments for Elementary/ Middle School served two purposes: (1) 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 and (2) to describe elementary/middle school teachers' strengths and weaknesses in mathematics knowledge so that teachers can make appropriate decisions with regard to courses or further professional development.

The assessments measured mathematics knowledge in four content domains (Whole Number/Computation, Rational Number/Computation, Geometry/Measurement, and Probability/Statistics/Algebra). Each assessment was composed of 20 items—10 multiple-choice and 10 open-response. Six versions of each assessment were available in paper-and-pencil
format so that researchers, professional development providers, and course instructors can administer them as pre- and post-tests before and after workshops, institutes, or courses to determine growth in teachers' content knowledge.

Three strategies were used to ensure the validity of the four mathematics assessments. First, as already described, the breadth and depth of mathematics content necessary for elementary teachers was defined by using national recommendations, objectives of standardized tests, and research on misconceptions for both middle school students and teachers. Second, teams composed of mathematicians, mathematics educators, and middle school teachers were used to create the Elementary Teacher Mathematics Content Summary Chart and to develop prototype and parallel assessments. Third, national reviewers were used to assess the appropriateness of items created for the six forms of the four assessments. The 24 assessments (six forms of the four assessments) were sent to 35 mathematicians, mathematics educators, and middle school mathematics teachers across the country. These educators had responded to a national call for assessment reviewers. Each reviewer analyzed four sets of assessments. For each item on the assessments, reviewers were asked to (1) identify the mathematics content of the item from a list of specific topics (taken from item specification charts), (2) identify the knowledge type (I, II, III, IV), and (3) indicate if the item assessed important mathematics content for middle school teachers (high, medium, or low level of importance). The assessments were distributed to reviewers so that each of the 24 assessments was reviewed by at least six reviewers, with at least one mathematician, mathematics educator, and teacher reviewing each assessment. Therefore, the sets of six parallel items across all four assessments were reviewed by at least 36 different reviewers.
An item was deemed acceptable if (1) at least 60% of the reviewers identified it as assessing a particular content topic, (2) at least 60% of the reviewers identified it as assessing a particular knowledge type, and (3) at least 75% of the reviewers deemed it important knowledge for middle school teachers. Items that met all three of these criteria were included in the assessments. Items that met the last criteria and one of the first two criteria were revised, and items that met none of the criteria were omitted and replaced by a new item. Of the 80 sets of parallel items across the four assessments, 41 met acceptable criteria, and 39 were revised or rewritten. These 39 new or revised items were sent to 16 mathematicians, mathematics educators, and middle school teachers for an additional review. Of these 39 items, all but four (one from each assessment) met the three criteria above. These four items were revised based on comments from the 16 reviewers and included in the assessments.

The participants experienced an intensive, ongoing professional development program in math that aligns with their instructional responsibility. As such teachers were assessed with the tool that aligns with their instructional responsibilities, either the Math Diagnostic Assessment for Elementary Teachers, or The Math Diagnostic Assessment for Middle School Teachers. The assessments were used as a pre-test and post-test to measure the difference in teacher content knowledge and teacher pedagogical knowledge. The professional development program occurred over the course of 10 weeks. The timeline for administration was between March 2014 –June 2014 at the beginning and end of the intensive, ongoing professional development program. A research assistant administered the measurement and the University of Louisville Center for Research in Mathematics and Science Teacher Development scored the assessments.

**End of course evaluation.** At the conclusion of the ten-week professional development program, participants completed an end of course evaluation. The questionnaire consisted of
three question types. The first type of question was to report perceived value of professional development components along three continua, on a numbered scale. The three continua were labeled as content, pedagogy, and learning and have a range from zero to ten. Participants indicated the perceived value on the continua and the datum is placed on a three-dimensional graph that reveals each participant’s perceived value (Figure 6). This three-dimensional graph revealed the perceived value on a tri-plot as a cross. The left axis of the tri-plot represented the percentage of overall value attributed to content knowledge, pedagogy knowledge, and utilization. The use of tri-plots to visually represent perceived value allowed the theme of the course to emerge. The tri-plot revealed the average reported perceived value in three dimensions of the intensive, ongoing professional development.

The second question type also was designed with a numbered scale. For this type of questions participants indicated the perceived value of the components of the professional development on a four-point scale and through an open-ended question. One question related to the each of the components of effective professional development (i.e. opportunities for “hands-on work,” integration of content into the daily life of school, connected to other learning, and discussions among teachers) was rated on the scale.
The third question type was an open-ended question. The open-ended question asked participants to name the most useful component of the professional development that influenced their instruction of mathematics. A research assistant administered the end of the course survey on the last day of the intervention. Participants returned the completed paper-pencil questionnaire to the research assistant before exiting the site.

**End of program questionnaire.** An electronic survey developed from the core features of effective professional development was used to gather participant perceptual data on these features as they were perceived by the participants. After the last session of the ten-week, intensive, on-going professional development, nine of the participants voluntarily completed the nine item end of program questionnaire. Three of the questionnaire items were open-ended responses and the remaining six items were closed responses. Participants ranked their perception of the presence of the core features of professional development in the experiment for the close response items. The ranking scale consisted four degrees: lowest, low middle, middle
high, and highest. The core features listed included focus on content knowledge, active learning, coherence and public examination of practice phrased in terminology such as hands-on learning opportunities, integrations of the content into daily school life, connection to other professional learning and discussion among colleagues. The open response items allowed the participants to share what they enjoyed the most and liked the least about the professional development program. The final open response item permitted participants to share their perception of how they wished the instructor had conducted the professional development.

Data Analysis

**Preparation of the data file.** The first step in data analysis was preparation of the data file. To build the data file, the data on teacher content knowledge and teacher pedagogy were collected with the Diagnostic Mathematics Assessments for Elementary/Middle School. When teachers complete the pre and post-test they listed the last 4 digits of their social security number as an identification number. The University of Louisville Center for Research in Mathematics and Science Teacher Development graded the tests and returned the scores in an excel spreadsheet. The scores on individual items as well as scores grouped by knowledge level were included in the report. The individual item scores were input in the database as nominal variables and the total score as a continuous variable. There were six versions of each assessment so the pre-test and post-test consisted of different questions covering the same content.

**Item scoring.** Scores on individual items were found in columns listed 1-20. Items 1-5 assess memorized/factual knowledge, items 6-10 assess conceptual understanding, items 11-15 assess reasoning and problem solving, and items 16-20 assess pedagogical content knowledge. A column of X’s indicated that the particular item on the pre-assessment and/or post-assessments
contained an error, and any scores shown in these cells were omitted from the test results. Possible test points were adjusted accordingly.

Items 1-10 were multiple-choice items and were scored as either 0 points (incorrect) or 1 point (correct). Items 11-20 were open-response items and received scores up to 3 points. These 3 points were distributed such that 0 points or 1 point were assigned depending on whether or not teachers demonstrated memorized/factual knowledge or conceptual understanding. In addition, 0 points, 1 point, or 2 points were awarded depending on the degree to which teachers demonstrated appropriate reasoning or problem solving strategies in items 11-15 or pedagogical content knowledge in items 16-20. The first column for items 11-20 for each teacher represented the score for memorized/factual or conceptual knowledge embedded in the item and the second column represented the score for reasoning, problem solving, or pedagogical content knowledge.

**Knowledge type scores.** The cumulative scores for each knowledge type (Type I–memorized/factual knowledge; Type II–conceptual understanding; Type III–reasoning/problem solving; Type IV–pedagogical content knowledge are listed in these columns. Note that the memorized/factual knowledge and conceptual understanding scores from items 11-20 were included in this summary. Listed in the Possible Scores column were the highest possible score in that knowledge type on the assessment. The score totals at the bottom of these columns gave the overall score of all teachers in the four knowledge types. To compare across knowledge types, please take into account that the possible scores for each column are different.

**Subcategory scores.** The cumulative scores on the mathematical subcategories were listed in columns on the right-hand side of the summary sheet. The subcategories for each assessment are listed in Figure 7 below.
Figure 7. Diagnostic Teachers Assessments Mathematical Subcategories

The column labeled Possible Scores lists the highest possible score in each subcategory on the assessment. The score totals at the bottom of these columns gave the overall score of all teachers in the different subcategories. To compare across subcategories, please take into account that the possible scores for each column were different.

**Total scores.** The total scores for each teacher were listed in the last column on the right. (Note that this total was the same for the total listed under knowledge types. These totals were the same because the total scores were simply distributed among knowledge types in one set of columns and among subcategories in the other set of columns.) The total score for all teachers on the assessment was found in the lower right-hand corner of the summary. All versions of DTAMS had the same total possible score of 40 (1 point for each of 10 items; 3 points for each of 10 items), so these scores may be compared without adjustments.
A database of the described ordinal, continuous, and nominal variables was created by gathering the data, scoring the data if applicable, determining the type of scores to analyze, inputting the data in the program and cleaning the data for analysis (Muijs, 2011). Cleaning the data included the elimination of incomplete data and visibly inspecting the data that was sorted for accurate range of scores. The data was analyzed using *Statistical Package for Social Sciences (SPSS)* likely “the most common statistical data-analysis software package used in educational research” (Muijs, 2011, p. 73). The nominal and continuous variables, the research question seeking the impact of the intensive, ongoing professional development on teacher content knowledge and teacher pedagogical knowledge guided the selection of the statistics test.

**Choice of Statistical Techniques**

Qualitative and qualitative data were collected to measure the impact of intensive, ongoing professional development on teacher content knowledge, teacher pedagogical knowledge and the perceived presence of the core features of effective professional development. Descriptive Statistics were used to present quantitative descriptions in a manageable, simplified form and to describe what occurred in the data (Muijs, 2011). Looking at the distribution, central tendency and the dispersion of the Diagnostic Mathematics Assessments for Elementary/Middle School Teachers pretest and posttest scores allowed for examination of the impact of the intensive, ongoing professional development on teacher content knowledge and teacher pedagogical knowledge. The baseline data from the pretest were analyzed in regard to the posttest results in order to observe any changes in content knowledge and pedagogical content knowledge of the participants. Analysis of changes in scores between pre- and post-test scores by knowledge level, subcategories and total score separated the participants into a group that improved, a group that improved by just a little, and a group who
appeared to reverse progress. A paired samples t-test of the pre- and post-test knowledge levels, subcategories, and total scores revealed the significance of the change in scores. Additionally a three-dimensional analysis of perceived professional growth as a result of participating in the intensive, ongoing professional development was conducted. Perceived learning was attributed to cognition, content knowledge, or content pedagogical knowledge along three axes. The resulting tri-plot allowed the theme of the ongoing, professional development to emerge in a quantitative means.

Through the use of researcher created open-ended questions and an end of program evaluation data were collected to clarify participant perception of the presence of core features of effective professional development in the intensive, ongoing professional development. The ability to cross-reference the descriptive statistics with the tri-plot analysis and the open-ended questions provided increased validity of the data. For triangulation and reliability purposes close-ended questions were included in the end of program questionnaire conducted with a half of the participants.

**Reliability, Validity and Generalizability**

According to Cook and Campbell (1979), interaction of selection and treatment, interaction of setting and treatment and interaction of history and treatment threaten external validity. Reliability is often threatened by bias. And threats to generalizability occur when the researcher extends findings to past and future situations (Cresswell, 2011). The primary research questions of the proposed study were directly related to teacher content knowledge and teacher pedagogical knowledge. The other research question of the proposed study was related to the teacher perception of the presence of core features of effective professional development. The facilitator of the intensive, ongoing professional development was directly responsible for
presenting the core features either directly or indirectly to the participants. The Diagnostic Assessment of Teachers of Mathematics pretest was administered in March at the beginning of the intervention and the post test was administered in June following the treatment. The timing of the assessment may threaten the generalizability of the findings to other teachers who receive professional development during the spring semester of the school year. Teachers were recruited from participating local schools to voluntarily join the professional development treatment. The site of the professional development treatment was in a location away from any of the participating school districts. The convenience or intrinsic motivation of joining the treatment may threaten the generalizability of the interaction of selection and the treatment. The data will need to be considered in relation to these threats and Muijs (2011) suggestion of the conventional cut point of 0.005 to indicate statistical significance. This would mean that a significance level of less than 0.005 is statistically significant. Conducting the calculations and comparing the result to the aforementioned scales revealed if the proposed experimental effect is generalizable.

The reliability of the Math Pennsylvania State System of Assessment data was ensured in multiple ways. Test administration procedures for the Math PSSA were standardized and reviewed just prior to the annual test administration. The Pennsylvania Department of Education (PDE) required building principals to attend a PDE provided training in secure testing procedures. The building principals were required to in turn train their certified teaching staff as test administrators. In that test administration training it was emphasized that Pennsylvania educators not see or discuss the test items. All instructional supports that may be related the possible tested content were removed from view of the students. Additionally there were multiple versions of each Math PSSA test at every grade level so that even in one testing site
(classroom) it was highly unlikely that students sat next to another with an identical test. Test items for each area of eligible content tested are presented more than once within each test version. All public school students across Pennsylvania in grades 3-8 completed the assessments ensuring the experimental group will have student achievement data. The Math PSSA results were reported to the general public, directly to the associated schools and to the parents of individual students. If a student had missing components in their scaled or total scores the student file was listed as incomplete.

The depth and breadth of the Diagnostic Mathematics Assessment was based on the National Council of Teacher of Mathematics recommended standards, national and international test objectives and the mathematical content represented the literature on teaching mathematics in grades 3-8. Teams of mathematicians, mathematics educators were used to create the prototype assessments. National reviewers rated the assessment items in three areas. A test item was deemed acceptable if (1) at least 60% of the reviewers identified it as assessing a particular content topic, (2) at least 60% of the reviewers identified it as assessing a particular knowledge type, and (3) at least 75% of the reviewers deemed it important knowledge for middle school teachers. Items that met all three of these criteria were included in the assessments. Diagnostic Mathematics Assessment has six versions of each assessment so that the instrument was used as a pre-test and post-test. The Diagnostic Mathematics Assessment was not generalized to other groups of teachers because the sample of teachers taking the assessment may or may not be representative of teachers as a whole.

Protection of Human Rights

Assurances from all participating LEAs were obtained for all assessments and professional development trainings administered in accord with the proposed study design and
for the provision of annual data on school-level measures that were used the evaluation. All participants were clearly informed of their roles and responsibilities in evaluation data collection for the life of the Math and Science Partnership regardless of whether they continued to work in participating LEA if appropriate. An external scoring agency, the Lincoln Intermediate Unit and the LEAs’ governing body ensured compliance with Federal Human Subjects Protection regulations as well as Northeastern University’s IRB requirements.

Summary

The purpose of this study was to evaluate the impact of an intensive professional development program on teacher content and pedagogical knowledge as well as their perceptions of the presence of core features of identified effective professional development. Quantitative research, as described by Aliaga and Gunderson (2000), explains phenomena by collecting numerical data that are analyzed using mathematically based methods. Since this study collected numerical data on the outcomes of teacher content knowledge, teacher pedagogical knowledge and teacher perception as a result of experiencing the phenomena of an intensive, ongoing professional development program, aspects of the study aligned to quantitative methods. To enhance a deeper understanding of the phenomena, qualitative data was reviewed to assess participants’ perceptions. Qualitative data is not necessarily numerical and allowed the researcher to explore a phenomenon from the perspective of the participants (Cresswell, 2012). According to Cresswell (2012), the combination of quantifiable and qualitative data provides a deeper understanding than either simply quantitative or qualitative data provide independently. Following the seminal research designs of the Math and Science Partnership program raised the priority of the quantitative data. Extending beyond the Math and Science Partnership programs’ research design enhanced the depth of understanding of the phenomenon by learning from those
participating in the experiment. Thus, an outcome evaluation design was employed to better understand the results of the research question - what is the impact of intensive, ongoing professional development on teacher content knowledge and teacher pedagogical knowledge from both a quantitative and qualitative perspective.

The empirical studies on effective professional development evaluated over two decades of outcomes from the Math and Science Partnership (MSP) programs. The data collection tool outlined by the MSP program measured the output of enhanced knowledge and skill aligns to quantitative results. The same quantitative tool used in the MSP mathematical component, The Diagnostic Teacher Assessments in Mathematics, was also utilized in this study. For the purpose of this study, a qualitative tool was included to enhance the Math and Science Partnership methodology. An outcome evaluation design was employed so that the results were aligned to the MSP annual reports and so that the results contributed to the larger field of longitudinal studies on MSPs and the systems of effective professional development.

The intensive, ongoing professional development program effects were produced in the complexity of a real school setting and classrooms, providing a good way to evaluate a new format of professional development. The effect of the professional development between teacher content knowledge and teacher pedagogy knowledge was not a result of confounding variables because the treatment was ten weeks of intensive on-going professional development throughout the school year and was unlikely to be otherwise available to the subject.

**Chapter IV: Research Findings**

**Reporting of the Findings and Analysis**

This outcome evaluation study was conducted in order to determine the impact of an intensive, ongoing professional development program focused on the development of teacher
content knowledge, pedagogical knowledge, as well as their perception of the presence of core features of the program. Three questions guided this study:

1. What is the impact of an intensive, ongoing professional development program on K-8 teachers’ mathematical content knowledge?
2. What is the impact of an intensive, ongoing professional development program on K-8 teachers’ pedagogical knowledge?
3. How did teachers of grades K-8 perceive the presence of the core features of effective professional development in the intensive, ongoing professional development?

This chapter presents the findings and analysis of data from pre- and post-test, close-ended questions and open-ended questions. The conceptual framework representing the identified core features and expected outcomes of effective professional development will be revisited to consider if the data collected in this study supports the expected outcome of enhanced knowledge and skill. Each finding is discussed and supported with data collected during the professional development program from pre- and post-test (Appendix C), end of program evaluation (Appendix B) and end of program questionnaire (Appendix D).

**Study Context**

The purpose of this study was to determine the impact of an intensive, ongoing professional development program focused on the development of teacher content knowledge, pedagogical knowledge, as well as learn their perception of the presence of core features of the program. A professional development program that focused on one mathematical strand (intensive) for 10 weeks (ongoing) was offered by a professional development provider and regional educational service provider. The number of contact hours for a weekly session was three, creating a sustained time of thirty hours for the program. Teachers of mathematics
representing multiple school districts registered and completed the intensive, ongoing professional development program. Seventeen teachers of mathematics completed pretest and posttest assessments measuring content knowledge and pedagogical content knowledge of the mathematical strand Numbers and Operations. Multiple-choice items assessed pedagogical content knowledge, as well as three categories of content knowledge: memorized/factual knowledge; conceptual understanding; reasoning and problem solving. Participants were asked to choose one of the four possible answer choices and show all mathematical work when responding to items and briefly explain thinking on all items. The quantitative data further clarified the depth of content knowledge the participants possessed before and after the professional development program. The end of program evaluation generated a mix of quantitative and qualitative data to understand perceived professional development gain, ranking of the instructor’s facilitation, identification of the most useful concept, and one suggestion for the instructor. Reporting of perceived professional development growth along three continua was quantified by the participant’s placement of an X on a ten-centimeter line. The ranking of the instructor’s facilitation in four areas was indicated on a four-point scale generating additional quantitative data. Qualitative data was generated from two open-ended questions, which invited all respondents to comment on the most useful concept and one suggestion for the instructor. The end of program questionnaire also generated a mix of qualitative and quantitative data. Rating the perceived presence of the core features of effective professional development generated quantitative data. Two open-ended response questions invited participants to share the best and worst aspects of the professional development program and produced qualitative data. The mix of quantitative and qualitative data further clarified and validated responses in regard to the impact of intensive, ongoing professional development on teacher content knowledge and
pedagogical knowledge, as well as their perception of the presence of core features of the program.

Penna & Phillips, (2005) indicated that outcome evaluation studies are grounded in a program’s theory of change and are well suited for program evaluation. Miles & Huberman (1994) explain the intertwining of quantitative outcomes of a study and qualitative processes as a “very powerful mix” and Green & Caracelli (1997) describe the mix as a means to “develop a complex picture of a social phenomenon.” Thus, data related to the guiding questions are shared within the framework of this chapter to clarify and qualify the responses of participants. Each guiding question of this study is related to the corresponding data collected by the researcher that provides a qualified description of results. The data for this study were triangulated through the use of pretest and posttest, end of program evaluation and focus group surveys.

Research Findings

The pretest and posttest (Appendix C) obtained from the University of Louisville asked twenty multiple-choice questions regarding content knowledge and pedagogical knowledge in one mathematical strand specifically related to the content the intensive, ongoing professional development program. The questions were classified into four categories: 1) memorized/factual knowledge, 2) conceptual understanding, 3) reasoning and problem solving, and 4) pedagogical content knowledge. Participants completed either the Diagnostic Teacher Assessments in Mathematics Middle School Numbers and Computation Assessment version 3 or the Diagnostic Teacher Assessment in Mathematics Elementary Numbers and Computation version 3.3 as a pretest prior to the first session of the intensive, ongoing professional development. At the conclusion of the last session of the intensive, ongoing professional development participants completed either the Diagnostic Teacher Assessments in Mathematics Middle School
Mathematics Numbers and Computation Assessment version 5 or the Diagnostic Teacher Assessment in Elementary School Mathematics Whole Number and Computation version 5.3 as a posttest. Participants’ responses to the pretest provided baseline data prior to the implementation of the intensive, ongoing professional development. In each of the four categories, participants demonstrated an increased mean from pretest to posttest. Not all participants increased their performance from pretest to posttest in the knowledge types. The participants increased their content knowledge in the subcategories of whole number, operational & computation, and number theory. In addition to the pre- and post-test data, further data were collected in an end of program evaluation and end of the program questionnaire.

An end of program evaluation (Appendix B) obtained with permission from the National Institute of Advanced Teaching and Learning asked eight questions regarding perceived outcomes of the intensive, ongoing professional development. Participants indicated, with an X on a line, perceived professional development along three continua. For example, the placement of the X represented what portion of their professional growth was content knowledge compared to pedagogical knowledge. The Xs on the continua were quantified by measuring the location of the mark, a range from 0 to 10 centimeters. The value for each datum was entered into a triplot program—a program that placed each participant on a three-dimensional graph revealing individual perceived professional growth. Each participant’s perceived learning from a course is revealed on a triplot as a cross. The left axis of the triplot represents the percentage of overall learning attributed to teaching, or pedagogy, whereas the bottom axis represents learning and the right axis represents content knowledge (Figure 6). Participants reported their professional growth from the intensive, ongoing professional development was attributed to cognition or the
learning of mathematics more than the dimensions of teaching subject (content knowledge) or teaching (pedagogical knowledge).

Participants ranked the instructor’s facilitation of the workshop on a scale of one to four on the end of program evaluation. The participants rated the impact of the intensive, ongoing professional development on their professional growth the lowest and maintaining a professional climate was rated the highest. In addition to the quantitative scores, further data were collected when participants completed two open-ended response items that identified the most useful concept from the intensive, ongoing professional development and a suggestion for the program facilitator.

Figure 6. Triplot of Content Knowledge, Pedagogy, and Cognition

At the final session of the intensive, ongoing professional development, participants were offered the opportunity to participate in an end of program questionnaire. Nine of the participants voluntarily completed the nine item end of program questionnaire. Participants ranked their perception of the presence of the core features of professional development in the experiment for the close response items. The ranking scale consisted of four degrees: lowest, low middle, middle high, and highest. The core features listed included focus on content knowledge, active learning, coherence and public examination of practice phrased in
terminology such as hands-on learning opportunities, integrations of the content into daily school life, connection to other professional learning and discussion among colleagues. Participants perceived the core features of active learning and discussion among colleagues were present in the intensive, ongoing professional development program. The open response items allowed the participants to share what they enjoyed the most and liked the least about the professional development program.

**Analysis**

**Research question one.** The first guiding question of this study inquired about the impact of an intensive, ongoing professional development program on K-8 teachers (N=18) mathematical content knowledge. Pre- and post-test assessments asked twenty questions in Whole Numbers and Computation, which focused on four levels of knowledge (1) memorized/factual knowledge, (2) conceptual understanding, (3) reasoning or problem solving, (4) pedagogical content knowledge and three subcategories (1) whole numbers, (2) operations/computation, and (3) number theory.

Knowledge Level I: Memorized/Factual Knowledge asked participants to calculate measure, apply a rule or apply an algorithm in the subcategories of whole numbers, rational numbers, operations/computation and number theory of the mathematical strand Numbers and Operations. Knowledge Level II: Conceptual Understanding asked participants to explain the meaning of a concept from the subcategories of whole numbers, rational numbers, operations/computation and number theory. Knowledge Level III: Reasoning or Problem Solving asked participants to go beyond the cognitive capability of explanation to supporting the explanation with evidence. Knowledge Level IV: Pedagogical Content Knowledge asked participants to use higher order thinking processes to solve real-world problems with
unpredictable outcomes in the subcategories of whole numbers, rational numbers, operations/computation and number theory.

**Pre- and post-test results.** The pre- and post-test data collected from the teachers indicate the impact of the intensive, ongoing professional development on teacher content and pedagogical knowledge. The pre- and post-test data is reported by individual items as well as by Knowledge Level and by subcategories of Numbers and Operations. The changes in score by knowledge level show the change in scores in regards to Knowledge Levels I, II, III and IV. Further changes in content knowledge are revealed through changes in scores by the subcategories scores of Whole Numbers, Rational Numbers, Integers, Operations/Computation, and Number Theory. The information presented in Table 6 shows the distribution of pre- and post-test scores of participants who teach grades K-6 (Elementary) and Table 7 shows the distribution of scores of the participants who teach grades 7 and 8 (Middle School). The raw data of the pre-test and post-test scores by knowledge level are displayed in Table 8 and Table 9. The raw data of the pre- and post-test scores by subcategory are presented in Table 10 and Table 11. The scores in Knowledge Level I: Memorized/Factual Knowledge spanned four points on the pre-test and five points on the post-test. The mode for the pre-test was eight and nine correct and ten correct was the data set that appeared most often on the post-test. From pre- to post-test, six of the elementary teachers (N=10) earned a higher score or exactly the same score. Four of the elementary participants (T0448, T2006, T8136, and T9166) decreased by one point from pre- to post-test in this category. Four of the middle school teachers (N=8) increased or stayed the same in the cognitive domain of Knowledge Level I. Four of the middle school teachers (T0612, T2431, T6861, and T9354) decreased by one or two points from pre- to post-test in this knowledge level. None of the participants (N=18) earned less than four points on the
memorization/factual knowledge questions. The lowest pre and post-test score in this knowledge level were attributed to an elementary special education teacher (T2006) and a middle school principal (T2431). The elementary special education teacher (T2006) wrote, “I don’t know” as a response for four or more problems on each assessment without indicating a choice of a, b, c or d. Sixteen of the participants (N=18) selected at least one close-ended response for questions 1-10 on the assessment. The Knowledge Level I: Memorized/Factual Knowledge questions were included within those ten multiple choice items. Four teachers (T3809, T8136, T0612, and T9534) earned a perfect score in the category on the pretest and seven teachers (T3809, T6861, T7186, T8180, T2539, T0493, and T5206) earned perfect marks on the post-test in this

<table>
<thead>
<tr>
<th>Knowledge Level</th>
<th>Pretest</th>
<th>Frequency of Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 1 2 4 5 6 7 8 9 10</td>
<td></td>
</tr>
<tr>
<td>I: Memorization</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pretest</td>
<td>1 1 3 3 2</td>
<td></td>
</tr>
<tr>
<td>Posttest</td>
<td>1 1 3 2 4</td>
<td></td>
</tr>
<tr>
<td>II: Conceptual Understanding</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pretest</td>
<td>1 1 1 5 2</td>
<td></td>
</tr>
<tr>
<td>Posttest</td>
<td>1 4 3 2</td>
<td></td>
</tr>
<tr>
<td>III: Reasoning</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pretest</td>
<td>1 1 2 1 1 2 2</td>
<td></td>
</tr>
<tr>
<td>Posttest</td>
<td>1 1 1 1 2 1 3</td>
<td></td>
</tr>
<tr>
<td>IV: Pedagogical</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pretest</td>
<td>1 2 3 4</td>
<td></td>
</tr>
<tr>
<td>Posttest</td>
<td>1 2 4 2 1</td>
<td></td>
</tr>
</tbody>
</table>

N=10
knowledge level. One teacher (T3809) earned perfect marks on both the pre- and post-test in Knowledge Level I: Memorized/Factual Knowledge. Using the t-test for paired samples, the difference between pre- and post- test Knowledge Level I scores were not found to be significant \( t = -0.244, df = 8, \text{sig} = .813 \). Middle School \( t = .475, df = 7, \text{sig} = .649 \)

Knowledge Level II: Conceptual Understanding asked the teachers to accurately answer the questions and explain, “why it is so.” Table 6 and Table 7 display the distribution of pre-test and post-test scores for this knowledge level. The pre-test scores of the elementary teachers span a six-point range and three points on the post-test. The mode was nine points on the elementary pre-test and eight points on the post-test. The middle school teachers scores spanned three points on the pre-test and four points on the post-test. The mode on the middle school pre-test was six points and the mode was seven points and eight points on the post-test. Thirteen of the middle school participants \( (N=18) \) gained or maintained an equivalent score in conceptual understanding as shown in Table 8 and Table 9. The five teachers (T0448, T6786, T0612, T2431, and T5206) who scored lower on the post-test than the pre-test by one or two points, skipped entire questions or did not explain their reasoning on some of the questions. On the pretest there were nine participants who scored four, five, or six points out of ten possible points. On the post-test all participants earned seven or more points, showing an increase in conceptual understanding and the ability to explain their answer. The elementary special education teacher (T2006) who scored a four on the pre-test and nine on the post-test wrote, “I don’t know” on four pre-test questions and two post-test questions. The participant with the lowest post-test score for Knowledge Level II was the middle school administrator (T2431). He did show his mathematical calculations but did not explain his reasoning on at least eleven questions. Two elementary teachers (T3809, T8180) and one middle school teacher (T0493) had perfect scores
on the posttest with Knowledge Level II questions. The same three teachers also had perfect post-test scores in Knowledge Level I, showed their mathematical calculations and provided detailed responses explaining their reasoning. Using the t-test for paired samples, the difference between pre- and post-test Knowledge Level II: Conceptual Understanding scores were not found to be significant (t = -.645, df = 8, sig. = .537). Middle School (t= -2.434, df =7, sig. = .045)

Prior to participation in the intensive, ongoing professional development program, the Knowledge Level III: Reasoning/Problem Solving pre-test scores were distributed across a nine point range for the elementary teachers and a five point range for the middle school participants. The middle school teachers earned five points or more in this category on the pretest and six of those teachers had scores of eight, nine or ten. By the end of the professional development program, the range of scores for the elementary teachers was eight with a mode of ten. On the post-test the range expanded to nine points for the middle school teachers and the mode was ten. By the conclusion of the professional development program, eleven of the participants (N=18) maintained or improved their reasoning/problem skills shifting the results to a range of five points. An elementary teacher (T7186) earned zero points on the pretest in this Knowledge Level and improved by eight points on the post-test. This particular participant did not explain their reasoning on the pre-test. Two participants (T0612, T6861) both middle school teachers earned all possible points in Knowledge Level III: Reasoning/Problem Solving on the pre-test. In their answers these middle school teachers not only completed each part of each item, they also explained the reasoning of the correct answer. Some questions have up to three parts to form a complete answer. On the posttest, three elementary teachers (T8136, T8180, T9166) and three middle school teachers (T0493, T5206, T6861) earned all possible points in Knowledge
Level III by accurately answering the questions, showing mathematical calculations and supporting explaining their answers. Seven of the participants (N=18) decreased in scores from pre-test to post-test. An elementary teacher (T6786) who decreased from pre- to post-test did not attempt to explain her reasoning on multiple questions and wrote explanations that could be considered humorous for two items. T0258, T0612 and T9354 answered every question on the pre-test, did not explain their reasoning on two post-test questions and scored lower on the post-test than pre-test. T0448 left four questions blank on the pretest, did not explain their reasoning on two questions and had lower post-test scores. Using the t-test for paired samples, the difference between pre- and post- test Knowledge Level II: Conceptual Understanding scores were not found to be significant (t =1.93, df = 8, sig. = .090). Middle School (t= .918, df =7, sig = .389)

From pretest to posttest the total scores varied between the knowledge levels and between the elementary and middle school teacher groups (Table 6 and Table 7). The elementary teacher group improved in Knowledge Level I: Memorization /Factual and Knowledge Level III: Reasoning/Problem Solving by three points and twenty points respectively. In Knowledge Level II: Conceptual Understanding, the elementary teacher group scored four fewer points on the post-test than the pre-test. The middle school teacher group improved in Knowledge Level II: Conceptual Understanding by eleven points and Knowledge Level III Reasoning or Problem Solving by three points. The middle school teacher group decreased in Knowledge Level I: Memorized/Factual Knowledge by two points. Both teacher groups improved in Knowledge Level III: Problem Solving/Reasoning and in total score from pre- to post-test. Middle School (t = -1.309, df =7, sig = .232)
Table 7

Middle School Knowledge Level Scores from Pre- to Post-test

<table>
<thead>
<tr>
<th>Knowledge Level</th>
<th>Frequency of Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td>I: Memorization</td>
<td>Pretest</td>
</tr>
<tr>
<td></td>
<td>Posttest</td>
</tr>
<tr>
<td>II: Conceptual Understanding</td>
<td>Pretest</td>
</tr>
<tr>
<td></td>
<td>Posttest</td>
</tr>
<tr>
<td>III: Reasoning</td>
<td>Pretest</td>
</tr>
<tr>
<td></td>
<td>Posttest</td>
</tr>
<tr>
<td>IV: Pedagogical Knowledge</td>
<td>Pretest</td>
</tr>
<tr>
<td></td>
<td>Posttest</td>
</tr>
</tbody>
</table>

N=8

Further examination of individual participant’s responses revealed the degree to which the teacher answered all aspects of the question by showing mathematical work and briefly explaining their reasoning impacted the score earned. Teachers (T3809, T8136, T9166, T0612) who maintained their total scores within one point from pre- to post-test scores did not maintain the exact pre- and post-test scores in Knowledge Level I, II, or III. One teacher (T3809) earned all possible points in Knowledge Level I and Knowledge Level II but did not earn all possible points in Knowledge Level III, while another participant (T8180) earned all possible points in Knowledge Level III. Two participants (T2006 and T7186) with pre-test scores under 17 points increased the most from pre-test to post-test. Five participants (T0448, T6796, T9611, T2431,
Table 8

*Elementary Teachers Pre- to Post-test Scores by Knowledge Level*

<table>
<thead>
<tr>
<th></th>
<th>Pre I</th>
<th>Post I</th>
<th>Pre II</th>
<th>Post II</th>
<th>Pre III</th>
<th>Post III</th>
<th>Pre IV</th>
<th>Post IV</th>
<th>Pre Total</th>
<th>Post Total</th>
<th>Gain</th>
<th>Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Possible</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>40</td>
<td>40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0448</td>
<td>9</td>
<td>8</td>
<td>10</td>
<td>8</td>
<td>7</td>
<td>6</td>
<td>6</td>
<td>33</td>
<td>24</td>
<td>-9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2006</td>
<td>6</td>
<td>5</td>
<td>4</td>
<td>9</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>12</td>
<td>24</td>
<td>+12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3809</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>8</td>
<td>9</td>
<td>7</td>
<td>6</td>
<td>35</td>
<td>35</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>6786</td>
<td>8</td>
<td>9</td>
<td>9</td>
<td>8</td>
<td>4</td>
<td>2</td>
<td>6</td>
<td>5</td>
<td>27</td>
<td>24</td>
<td>-3</td>
<td></td>
</tr>
<tr>
<td>6861</td>
<td>8</td>
<td>10</td>
<td>9</td>
<td>9</td>
<td>5</td>
<td>8</td>
<td>6</td>
<td>7</td>
<td>28</td>
<td>34</td>
<td>+6</td>
<td></td>
</tr>
<tr>
<td>7186</td>
<td>7</td>
<td>10</td>
<td>6</td>
<td>8</td>
<td>0</td>
<td>8</td>
<td>4</td>
<td>4</td>
<td>17</td>
<td>30</td>
<td>+13</td>
<td></td>
</tr>
<tr>
<td>7550</td>
<td>8</td>
<td>8</td>
<td>9</td>
<td>8</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>7</td>
<td>25</td>
<td>30</td>
<td>+5</td>
<td></td>
</tr>
<tr>
<td>8136</td>
<td>10</td>
<td>9</td>
<td>7</td>
<td>7</td>
<td>8</td>
<td>10</td>
<td>6</td>
<td>6</td>
<td>31</td>
<td>32</td>
<td>+1</td>
<td></td>
</tr>
<tr>
<td>8180</td>
<td>9</td>
<td>10</td>
<td>9</td>
<td>10</td>
<td>9</td>
<td>10</td>
<td>7</td>
<td>8</td>
<td>34</td>
<td>38</td>
<td>+4</td>
<td></td>
</tr>
<tr>
<td>9166</td>
<td>9</td>
<td>8</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>10</td>
<td>7</td>
<td>6</td>
<td>34</td>
<td>33</td>
<td>-1</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>84</td>
<td>87</td>
<td>86</td>
<td>82</td>
<td>55</td>
<td>75</td>
<td>55</td>
<td>60</td>
<td>276</td>
<td>308</td>
<td>+32</td>
<td></td>
</tr>
</tbody>
</table>

N=10

and T9354) had lower post-test scores than pre-test scores. T0048 left three questions completely blank on the post-test. T6796 did not show mathematical calculations on eleven questions and did not explain their reasoning on fourteen of the post-test items while T2431 did not show mathematical work for ten items and did not complete all aspects of the multiple part questions for two items on the post-test. T9354 answered all questions but made a mathematical error on one question and gave the reasoning “guess and check” for another item which did not
earn points. T9611 made one more mathematical error on the post-test than on the pre-test, causing her total score to decrease by one point. The fourteen participants who answered all questions as completely as possible, showed all work in response to items and briefly explained thinking on all items increased their total score from pre-test to post-test. Using the t-test for paired samples, the difference between pre- and post-test scores was not significant for each of the Knowledge Types: Knowledge Level I: Memorized/Factual; Knowledge Level II: Conceptual Understanding; and Knowledge Level III: Reasoning/Problem Solving.

The subcategories of Whole Numbers, Rational Numbers, Operations/Computation, Integers, and Number Theory align to the mathematical strand of Numbers and Operations. Teacher content knowledge in the aforementioned subcategories was collected through the pre- and post-test assessments. Table 6 and Table 7 show the distribution and frequency of results of the pre- and post-test results by subcategory. The raw scores of the pre- and post-test are displayed by the subcategories in Table 8 and Table 9.

Whole Numbers do not include negative numbers or parts of numbers (Rational Numbers) and are easily recognized as the numbers used to count. Participants were asked to solve problems with whole numbers by applying the rules of expanded notation, rounding, the commutative property, place value, etc. and explain their reasoning. In the subcategory of Whole Numbers the elementary teachers (N=10) range of scores spanned three points on the pre-test and two points on the post-test in their content knowledge. The scores of the middle school teachers spanned a seven point range on the pre-test and ten points on the post-test. Six points was the mode on the elementary pre- and post-test. The mode was twelve points on the pretest and fourteen points on the post-test for the middle school group. Fifteen of the participants (N=18) improved or maintained their scores in the subcategory of Whole Numbers from pre-
### Table 9

**Middle School Teachers Pre- to Post-test Scores by Knowledge Level**

<table>
<thead>
<tr>
<th></th>
<th>Pre I</th>
<th>Post I</th>
<th>Pre II</th>
<th>Post II</th>
<th>Pre III</th>
<th>Post III</th>
<th>Pre IV</th>
<th>Post IV</th>
<th>Total</th>
<th>Pre Total</th>
<th>Post Total</th>
<th>Gain</th>
<th>Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Possible</td>
<td>11</td>
<td>11</td>
<td>9</td>
<td>9</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>40</td>
<td>40</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0258</td>
<td>9</td>
<td>9</td>
<td>8</td>
<td>8</td>
<td>7</td>
<td>8</td>
<td>6</td>
<td>6</td>
<td>26</td>
<td>30</td>
<td>+4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0493</td>
<td>9</td>
<td>11</td>
<td>6</td>
<td>9</td>
<td>5</td>
<td>10</td>
<td>6</td>
<td>9</td>
<td>29</td>
<td>39</td>
<td>+10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0612</td>
<td>10</td>
<td>9</td>
<td>5</td>
<td>8</td>
<td>10</td>
<td>6</td>
<td>5</td>
<td>7</td>
<td>30</td>
<td>30</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>2431</td>
<td>6</td>
<td>4</td>
<td>6</td>
<td>5</td>
<td>6</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>20</td>
<td>14</td>
<td>-6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2539</td>
<td>9</td>
<td>10</td>
<td>5</td>
<td>7</td>
<td>9</td>
<td>7</td>
<td>4</td>
<td>8</td>
<td>27</td>
<td>32</td>
<td>+5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5206</td>
<td>9</td>
<td>11</td>
<td>9</td>
<td>8</td>
<td>5</td>
<td>8</td>
<td>6</td>
<td>8</td>
<td>28</td>
<td>33</td>
<td>+5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6861</td>
<td>11</td>
<td>10</td>
<td>6</td>
<td>8</td>
<td>10</td>
<td>10</td>
<td>5</td>
<td>8</td>
<td>32</td>
<td>36</td>
<td>+4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9354</td>
<td>10</td>
<td>8</td>
<td>6</td>
<td>7</td>
<td>9</td>
<td>6</td>
<td>7</td>
<td>9</td>
<td>32</td>
<td>30</td>
<td>-2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>74</td>
<td>72</td>
<td>48</td>
<td>59</td>
<td>65</td>
<td>68</td>
<td>42</td>
<td>58</td>
<td>229</td>
<td>247</td>
<td>+18</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

N=8

post-test (Table 8 and Table 9). Between the pre- and post-tests seven teachers maintained the exact same scores from pre- to post-test. Eight of the elementary teachers improved in this subcategory. Two elementary teachers (T0448 and T7550) decreased from pre- to post-test in the subcategory of Whole Numbers by one point, indicating an error in calculation. One participant (T8180) earned perfect marks in this subcategory on both the pre- and post-test. The total possible points on the middle school version of the assessment were fifteen. One teacher (T5206) earned all fifteen points on the post-test in this subcategory. Two of the middle school teachers (T0612 and T2431) decreased in scores by three points and two points respectively.
between the pre- and post-test. Scores in the subcategory of Numbers and Operations reflected accuracy in solving problems and attempting to complete each problem. Using the t-test for paired samples, the difference between pre- and post-test subcategory of Whole Number scores were not found to be significant (t = .000, df = 8, sig. = 1.00). Middle School (t = -.893, df = 7, sig = .402)

The subcategory of Operations/Computation only applies to elementary version of the Diagnostic Teacher Assessments in Mathematics Whole Number & Computation Assessment. The total possible points in this subcategory were twenty-four. The results of the pre-test spanned a range of twenty points on the pre-test and ten points on the post-test. On the pre-test every teacher (N=10) had a different score. On the post-test the mode was twenty-two points. Six of the elementary teachers (N=10) improved scores by at least one point from pre- to post-test. Three elementary teachers (T0488, T3809, and T6796), decreased scores by three, one and two points respectively, and another participant (T9611) had the exact same score from pretest to posttest. Two elementary teachers improved their post-test scores by two or more points. Not one teacher earned a perfect score on either the pre- or post-test. Scores in the subcategory of Operations/Computation reflected accuracy in solving problems and attempting to complete each problem. Using the t-test for paired samples, the difference between pre- and post-test subcategory of Operations/Computation scores were not found to be significant (t =1.615, df = 8, sig. = .145).

Rational Numbers and Integers are subcategories that are associated to the middle school version of the Diagnostic Teacher Assessments in Mathematics Number and Computation Assessment. There were nine possible points in both the Rational Number and Integers subcategories. In the subcategory of Rational Numbers, participants are asked to solve
Table 10

*Frequency of Elementary Teachers Pre- and Post-test scores by Subcategories*

<table>
<thead>
<tr>
<th>Subcategories</th>
<th>Frequency of Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3 4 5 6 7 8 12 13 14 16 17 18 19 20 21 22 23</td>
</tr>
<tr>
<td>Whole Numbers</td>
<td>Pre 1 2 6 1</td>
</tr>
<tr>
<td></td>
<td>Post 3 6 1</td>
</tr>
<tr>
<td>Operations/Comp</td>
<td>Pre 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1</td>
</tr>
<tr>
<td></td>
<td>Post 1 1 2 1 1 1 1 1 1 3</td>
</tr>
<tr>
<td>Number Theory</td>
<td>Pre 1 3 5 1</td>
</tr>
<tr>
<td></td>
<td>Post 5 3 2</td>
</tr>
</tbody>
</table>

N=10

Mathematical problems with numbers that can be made by dividing one integer by another such as those found in ratios, fractions, and decimals. The Rational Numbers results spanned a range of three points on the pre-test and four points on the post-test. On the pre-test the mode was six points and on the post-test the mode was five points. Four of the middle school teachers (T0258, T2539, 5206, and T9354) scored from one to three points less between the pre- and post-test. Three of the middle school teachers (T0493, T0612, and T6861) improved by one to three points and one teacher (T2431) scored exactly the same from pre- to post-test. Three teachers (T0612, T0493, and T6861) earned all possible points on the post-test in the Rational Number subcategory. Scores in the subcategories of Rational Numbers and Integers reflected accuracy in solving problems and attempting to complete each problem. Using the t-test for paired samples, the difference between pre- and post-test subcategory of Rational Numbers scores were not found to be significant (t = -.134, df =7, sig. = .897).
The subcategory of Integers required participants to work with numbers that can be written without a fractional part. For example 21, 4, and −2048 are integers, while 9.75, 5½, and \(\sqrt{2}\) are not. In the Integers subcategory the scores were distributed across six points on the pre-test and seven points on the post-test. Five of the participants (T0258, T0493, T612, T2539, and T6861) improved their score by one or more points between assessments. Two teachers (T5206, T9354) scores were exactly the same on the pre- and post-test. One teacher (T0258) scored a point lower on the post-test and one participant (T2431) decreased in the category of Integers by three points. One teacher (T5206) earned all possible points in the subcategory of Integers on the pretest. On the post-test two teachers (T5206, T0493) earned all possible points in the Integers subcategory. Scores in the subcategories of Integers reflected accuracy in solving problems and attempting to complete each problem. Using the t-test for paired samples, the difference between pre- and post-test subcategory of Integers scores were not found to be significant \(t= -1.158, \text{df} = 7, \text{sig.} = .258\)

The subcategory Number Theory applies to both elementary and middle school mathematics. In the subcategory participants are required to solve problems about the properties of whole numbers including finding prime numbers and factoring numbers. The highest possible score a participant can earn in the category was nine points. On the elementary pre-test the participants’ scores ranged from four to seven points (Table 6). The range for the middle school teacher group spanned from one point to nine points (Table 7). On the post-test seventeen of the participants (N=18) earned scores in the range of six points to nine points. The middle school principal (T2431) scored a zero in the category on the post-test. Six of the teachers (T0448, T3809, T8136, T9611, T0612, T2431, and T6861) scored lower on the post-test than the pre-test
Table 11

*Frequency of Middle School Teacher Pre- and Post-test Scores by Subcategories*

<table>
<thead>
<tr>
<th>Subcategories</th>
<th>Frequency of Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Whole Numbers</td>
<td></td>
</tr>
<tr>
<td>Post</td>
<td>1</td>
</tr>
<tr>
<td>Rational Numbers</td>
<td></td>
</tr>
<tr>
<td>Post</td>
<td></td>
</tr>
<tr>
<td>Integers</td>
<td></td>
</tr>
<tr>
<td>Post</td>
<td></td>
</tr>
<tr>
<td>Number Theory</td>
<td></td>
</tr>
<tr>
<td>Post</td>
<td></td>
</tr>
</tbody>
</table>

N=8

by one or two points. The remaining participants (N=18) either earned the exact same score or improved their score by at least one point from pre-test to post-test. Scores in the subcategory of Number Theory reflected accuracy in solving problems and attempting to complete each problem. Using the t-test for paired samples, the difference between pre- and post-test subcategory of Number Theory scores were found to be significant (t =-.707, df = 8, sig. = .500). Middle School (t = -.723, df = 7, sig. = .232)

The Total Score of the subcategories is the sum of points earned in Whole Numbers, Integers, Rational Numbers, Operations/Computation and Number Theory. From pre-test to post-test the subcategory Total Scores varied between the subcategories and between the elementary and middle school teacher groups. Both the elementary and middle school teacher
groups improved scores between the pretest and post-test in all subcategories. The elementary teachers improved in the subcategory of Whole Numbers by one point, the subcategory of Operations/Computation by twenty-eight points and the subcategory of Number Theory by three points. The middle school teachers collectively improved in the subcategory of Whole numbers by six points, the subcategory of Rational Numbers by one point, the subcategory of Integers by six points and the subcategory of Number Theory by five points. The elementary teacher group made the greatest improvement in the subcategory of Operations/Computation with an eighteen point increase. The middle school group made the greatest improvement in the subcategories of Whole Numbers and Integers with an increase of six points in both subcategories. Subcategories Total Scores reflected accuracy in solving problems and attempting to complete each problem within the subcategories of Whole Numbers, Operations/Computation, Rational Numbers, Integers, and Number Theory. The difference between pre- and post-test scores, in the subcategory of Number Theory, was found to be significant. The difference in the pre- and post-test scores in the subcategories of Whole Numbers, Rational Numbers, Integers, Operations/Computation and Number Theory were not significant.
Table 12

*Elementary Teacher Pre- and Post-test Raw Scores by Subcategory*

<table>
<thead>
<tr>
<th></th>
<th>W# Pre</th>
<th>W# Post</th>
<th>Operations Pre</th>
<th>Operations Post</th>
<th>NT Pre</th>
<th>NT Post</th>
<th>Total Pre</th>
<th>Total Post</th>
<th>Gain</th>
<th>Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Possible</td>
<td>7</td>
<td>7</td>
<td>24</td>
<td>24</td>
<td>9</td>
<td>9</td>
<td>40</td>
<td>40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0448</td>
<td>6</td>
<td>5</td>
<td>19</td>
<td>16</td>
<td>8</td>
<td>7</td>
<td>33</td>
<td>28</td>
<td>-5</td>
<td></td>
</tr>
<tr>
<td>2006</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>13</td>
<td>4</td>
<td>6</td>
<td>12</td>
<td>24</td>
<td>+12</td>
<td></td>
</tr>
<tr>
<td>3809</td>
<td>6</td>
<td>6</td>
<td>23</td>
<td>22</td>
<td>6</td>
<td>7</td>
<td>35</td>
<td>35</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>6796</td>
<td>6</td>
<td>6</td>
<td>14</td>
<td>12</td>
<td>7</td>
<td>6</td>
<td>27</td>
<td>24</td>
<td>-3</td>
<td></td>
</tr>
<tr>
<td>6861</td>
<td>5</td>
<td>6</td>
<td>17</td>
<td>22</td>
<td>6</td>
<td>6</td>
<td>28</td>
<td>34</td>
<td>+6</td>
<td></td>
</tr>
<tr>
<td>7186</td>
<td>4</td>
<td>6</td>
<td>7</td>
<td>16</td>
<td>6</td>
<td>8</td>
<td>17</td>
<td>30</td>
<td>+13</td>
<td></td>
</tr>
<tr>
<td>7550</td>
<td>6</td>
<td>5</td>
<td>12</td>
<td>18</td>
<td>7</td>
<td>7</td>
<td>25</td>
<td>30</td>
<td>+5</td>
<td></td>
</tr>
<tr>
<td>8136</td>
<td>6</td>
<td>6</td>
<td>18</td>
<td>20</td>
<td>7</td>
<td>6</td>
<td>31</td>
<td>32</td>
<td>+1</td>
<td></td>
</tr>
<tr>
<td>8180</td>
<td>7</td>
<td>7</td>
<td>20</td>
<td>22</td>
<td>7</td>
<td>9</td>
<td>34</td>
<td>38</td>
<td>+4</td>
<td></td>
</tr>
<tr>
<td>9611</td>
<td>6</td>
<td>6</td>
<td>21</td>
<td>21</td>
<td>7</td>
<td>6</td>
<td>34</td>
<td>33</td>
<td>-1</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>57</td>
<td>58</td>
<td>154</td>
<td>182</td>
<td>65</td>
<td>68</td>
<td>276</td>
<td>308</td>
<td>+32</td>
<td></td>
</tr>
</tbody>
</table>

N=10
Table 13

*Middle School Teacher Pre- and Post-test Raw Scores by Subcategory*

<table>
<thead>
<tr>
<th>W# Pre</th>
<th>W# Post</th>
<th>R# Pre</th>
<th>R# Post</th>
<th>Int# Pre</th>
<th>Int# Post</th>
<th>NT Pre</th>
<th>NT Post</th>
<th>Total Pre</th>
<th>Total Post</th>
<th>Gain</th>
<th>Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Possible</td>
<td>15</td>
<td>15</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>7</td>
<td>7</td>
<td>40</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>0258</td>
<td>10</td>
<td>10</td>
<td>6</td>
<td>5</td>
<td>6</td>
<td>8</td>
<td>4</td>
<td>7</td>
<td>26</td>
<td>30</td>
<td>+4</td>
</tr>
<tr>
<td>0493</td>
<td>14</td>
<td>14</td>
<td>6</td>
<td>9</td>
<td>6</td>
<td>9</td>
<td>3</td>
<td>7</td>
<td>29</td>
<td>39</td>
<td>+10</td>
</tr>
<tr>
<td>0612</td>
<td>12</td>
<td>9</td>
<td>5</td>
<td>9</td>
<td>7</td>
<td>8</td>
<td>6</td>
<td>4</td>
<td>30</td>
<td>30</td>
<td>0</td>
</tr>
<tr>
<td>2431</td>
<td>7</td>
<td>5</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>20</td>
<td>14</td>
<td>-6</td>
</tr>
<tr>
<td>2539</td>
<td>10</td>
<td>13</td>
<td>8</td>
<td>5</td>
<td>5</td>
<td>7</td>
<td>4</td>
<td>7</td>
<td>27</td>
<td>32</td>
<td>+5</td>
</tr>
<tr>
<td>5206</td>
<td>12</td>
<td>15</td>
<td>6</td>
<td>5</td>
<td>9</td>
<td>9</td>
<td>6</td>
<td>7</td>
<td>33</td>
<td>36</td>
<td>+3</td>
</tr>
<tr>
<td>6861</td>
<td>12</td>
<td>14</td>
<td>7</td>
<td>9</td>
<td>6</td>
<td>7</td>
<td>7</td>
<td>6</td>
<td>32</td>
<td>36</td>
<td>+4</td>
</tr>
<tr>
<td>9354</td>
<td>11</td>
<td>14</td>
<td>8</td>
<td>5</td>
<td>8</td>
<td>8</td>
<td>5</td>
<td>3</td>
<td>32</td>
<td>30</td>
<td>-2</td>
</tr>
<tr>
<td>Total</td>
<td>88</td>
<td>94</td>
<td>52</td>
<td>53</td>
<td>53</td>
<td>59</td>
<td>36</td>
<td>41</td>
<td>229</td>
<td>247</td>
<td>+18</td>
</tr>
</tbody>
</table>

N=8

*End of program evaluation.* The impact of the intensive, ongoing professional development program on teacher content and pedagogical knowledge was further supported by the findings within the end of program evaluation. Teacher perception of professional growth as a result of participation in the program along three dimensions: learning (cognition); subject (content knowledge); and teaching (pedagogy) was shown in a triplot of content knowledge, pedagogy and cognition (Figure 6). On average, participants indicated that they learned more about the learning of mathematics, than pedagogy and subject knowledge. The dimension of learning of mathematics (cognition) was ranked highest by 38.85 percent of teachers. The
participants reported that the mathematics teaching or pedagogy was the second highest dimension with a ranking of 33.26 percent. The lowest reported dimension was mathematics content with a ranking of 27.44 percent. The end of program evaluation findings are consistent with the pre- and post-test findings that participants learned more about solving mathematical problems and explaining their reasoning than they did about mathematical pedagogy.

Figure 6. Triplot of Content Knowledge, Pedagogy and Cognition

The first guiding question of this study inquired about the impact of intensive, ongoing professional development program on K-8 teachers’ mathematical content knowledge. The data regarding this question provided evidence of an increase in content knowledge as a result of participation in an intensive, ongoing professional development program. Through multiple instruments, findings were recorded and reported as they relate to teacher content knowledge.
Positive impact on teacher content knowledge was seen from an evaluation of the outcomes of the intensive, ongoing professional development program.

**Research question two.** The second guiding question of this study inquired about the impact of an intensive, ongoing professional development program on K-8 teachers’ pedagogical knowledge. Pre- and post-test assessments asked twenty questions in the mathematical strand of Whole Numbers and Computation, which focused on four levels of knowledge: (1) memorized/factual knowledge, (2) conceptual understanding, (3) reasoning or problem solving, (4) pedagogical content knowledge. Knowledge Level 4: Pedagogical Knowledge provided insight to guiding question two. The impact of the intensive, ongoing professional development program on teacher pedagogical knowledge was further supported by the findings within the end of program evaluation.

**Pre and post-test results.** Knowledge Level 4: Pedagogical Content Knowledge asked participants to explain how to help a student understand a misconception identified in the student’s problem solving or to explain the correct procedure to solve a mathematical problem. There were ten possible points in the category. No participant earned all possible points on either the pre- or post-test with Knowledge Level 4: Pedagogical Knowledge questions (see Table 4.1 and Table 4.2). On the pretest the participant (N=17) scores ranged from one to eight points (see Table 4.1 and Table 4.2). On the post-test the results ranged from three to nine points. In this category, the mode for the elementary pre-test was seven points and six points for the post-test. The mode for the middle school pre-test was five points and eight for the post-test. Thirteen of the participants (N=17) increased or maintained their pedagogical knowledge by the end of the intensive, ongoing professional development program (see Table 8 and Table 9). Thirteen of the participants earned five, six, or seven points on the post-test by answering the
Knowledge Level IV: Pedagogical Knowledge questions correctly and displaying higher order thinking skills in their response. The middle school principal (T2431) had the lowest score in the middle school group, earning three points on both the pretest and post-test. Four elementary teachers (T0448, T6796, T3809, T9166) scored one point less on the post-test than they did on the pre-test. The middle school teacher (T0258) with a lower post-test than pre-test score regressed by two points. The participants who scored lower on the post-test than pre-test left one or more questions blank or did not explain how they would help a student understand. Using the t-test for paired samples, the difference between pre- and post-test Knowledge Level 4: Pedagogical Knowledge scores were found to be significant (t = .000, df = 8, sig. = 1.00). Middle school (t = -3.528, df = 7, sig. = .010)

**Tri-plot of Content Knowledge, Pedagogy and Cognition.** The impact of the intensive, ongoing professional development program on teacher content and pedagogical knowledge was further supported by the findings within the end of program evaluation. Participants reported perceptions of their personal professional growth as a result of participation in the program along three dimensions: learning (cognition); subject (content knowledge); teaching (pedagogy). A tri-plot (Figure 6) with the axis of content knowledge, pedagogy and cognition reveals participant perceptions that mathematics teaching or pedagogy was the second highest dimension with a ranking of 33.26 percent. On average participants indicated that they learned less about pedagogy than the learning of mathematics (cognition). The participants also indicated they learned more about pedagogy than subject knowledge (content knowledge). The dimension of learning of mathematics (cognition) was ranked highest by 38.85 percent of teachers. The lowest reported dimension was mathematics content with a ranking of 27.44 percent. The end of program evaluation findings are consist with the pre- and post-test findings in that participants
learned more about solving mathematical problems and explaining their reasoning than they did about mathematical pedagogy.

**Open-ended questions.** An open-ended question on the end of program evaluation gave participants the opportunity to identify the most useful concept from the intensive, ongoing professional development program that would influence their instruction of mathematics (pedagogy). The participants responded with a phrase, a sentence or two sentences. The phrase or initial sentences constitute the initial response and additional phrases or sentences are identified as the secondary response (Table 14). Fifteen participants identified Pedagogical Knowledge (N=17) as the most useful concept from the intensive, ongoing professional development program that will influence their instruction in mathematics (pedagogy). Facilitating discussion among students was identified, by one teacher (T2), as the most useful concept. Eleven teachers used phrases and sentences in their primary response that specifically named manipulatives, models, hands-on or visual models as the most useful concept that will influence their instruction of mathematics. Two additional teachers used the broader terms of “new ways of understanding” (T12), and “problem solving” (T16) without referencing a specific instructional strategy to identify the most useful concept. Another teacher used the phrasing of “…allow students to explore and experience math as a fun learning experience” (T18). Two other participants referenced “instructional strategies” (T14), or “good take-away” (T8) in their primary response but also specifically stated “it was difficult finding a way to apply the information to the classroom” or “…not sure the most useful concept that will really influence how I will teach math.” Neither of the aforementioned responses was attributed to the Pedagogical Knowledge or Content Knowledge.
In primary responses Content Knowledge was identified, by two participants, as the most useful concept. One teacher (T7) expressed that “the last concept—fractions, ratios and percents” as the most useful concept. One teacher used the phrase “dividing fractions using a common denominator” (T11), to indicate the most useful concept. Four teachers referenced content while indicating pedagogical knowledge in their response with phrases such as “area model for GCF/LCM” (T13), and “teaching Greatest Common Factor and Least Common Factor using Venn Diagrams – love it” (T10), and “Number theory concepts with visual models” (T9), and “area models were most useful for multiplications of fractions” (T3).

Table 14

Participant Perception of Pedagogical Influences

<table>
<thead>
<tr>
<th>Category:</th>
<th>Pedagogical Knowledge</th>
<th>Content Knowledge</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subcategory:</td>
<td>Discussion</td>
<td>Active Learning</td>
<td>Pedagogy</td>
</tr>
<tr>
<td>Key words:</td>
<td>discussion</td>
<td>manipulative</td>
<td>videos</td>
</tr>
<tr>
<td></td>
<td>models hands-on</td>
<td>instructional strategies</td>
<td>fun</td>
</tr>
<tr>
<td></td>
<td>visuals</td>
<td>problem solving</td>
<td>Venn diagram</td>
</tr>
<tr>
<td>Primary Response</td>
<td>1</td>
<td>9</td>
<td>2</td>
</tr>
<tr>
<td>Secondary Response</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

In responding to the open-ended question, four participants used a second phrase or sentence to describe the most useful concept from the intensive, ongoing professional development. Three participants referenced pedagogical Content Knowledge in secondary
responses. One teacher referenced active learning in a secondary response with the phrase “the area model of multiplication…” (T14). Two additional teachers provided secondary responses that broadly align to Pedagogical Content Knowledge by indicating, “the videos of others completing the tasks were useful as well (T3), and “I found some new ways to help my students learn math better” (T17).

The open-ended question on the end of course survey asked participants to identify the most useful concept from the intensive, ongoing professional development that will influence their instruction of mathematics. Thirteen teachers (N=17) responded with phrases or sentences that indicated pedagogical knowledge from the intensive, ongoing professional development will influence their instruction of mathematics. Pedagogical knowledge was also referenced in secondary responses by two additional teachers. Two teachers responded with phrases referring to mathematical concepts indicating that content knowledge was the most useful concept from the program. The remaining two teachers mentioned “good takeaways” and “some different ways of looking at math” but did not indicate the most useful concept that will influence their instruction of mathematics. The open-ended results mirror the improved Knowledge Level 4: Pedagogical Knowledge improvements from pre-test to post-test in all participant maintained or improved in scores from pre- to post-test in this category and fifteen participants (N=17) named pedagogical knowledge as the most useful concept from the intensive, ongoing professional development program. The open-ended results do not reflect the results of the triplot of perceived professional growth in that participants did not perceive mathematics teaching or pedagogy as the highest dimension of their professional growth.

**Research question three.** The third guiding question of this study inquired how did teachers of grades K-8 perceive the presence of the core features of effective professional
development in the intensive, ongoing professional development. The end of program questionnaire asked participants to rate the presence of core features of effective professional development on a four point Likert scale. Open-ended questions on the end of program questionnaire asked the teachers to share the best and worst aspects of the intensive, ongoing professional development program. The end of program evaluation included an open-ended question asking participants to offer one suggestion for the professional development provider to improve the facilitation of the program.

**Close-ended questions.** On the end of program questionnaire, participants were given the opportunity to rate the perceived presence of the identified core features of effective professional development. The presence of each core feature was compared to a four point Likert scale with one point equating to the “lowest” rating and four points equating to the “highest” rating. The rankings between the “highest” and “lowest” included three points as the “middle-high” rating and two points as the “low-middle” rating. Nine of the participants (N=17) voluntarily completed four close-ended questions. Table 15 displays the frequency of responses by the core features of Active Learning, Focus on Content Knowledge, Coherence, and Public Examination of Practice. The first question, which aligns to the core feature of Active Learning, inquired if the instructor provided opportunities for hands-on learning in the intensive, ongoing professional development. The participants (N=9) indicated that active learning was present in the intensive, ongoing professional development with all respondents rating the core feature as either “middle-high” or “highest.” Four participants rated the presence of active learning with the “highest” rating and five participants rated the presence of active learning with a “middle-high” rating. The ratings of “lowest” and “low-middle” were not utilized by participants when
responding to the question about the perceived presence of active learning in the intensive, ongoing professional development.

Table 15

*Frequency of Responses Rating Presence of Core Features*

<table>
<thead>
<tr>
<th>Core Feature</th>
<th>1-Lowest</th>
<th>2-Low Middle</th>
<th>3-Middle High</th>
<th>4-Highest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active Learning</td>
<td></td>
<td></td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Focus on Content</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Knowledge</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coherence</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Public Examination of Practice</td>
<td>1</td>
<td>3</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

N=9

Question two on the end of program questionnaire asked participants to rank how well the instructor integrated the content of the intensive, ongoing professional development program into their daily school life. This question aligns to the core feature of Focus on Content Knowledge. The participant (N=9) responses ranged across all four rating categories from “lowest” to “highest.” Three participants rated the integration of content into daily school life as the “lowest” and an additional three participants rated this core feature as “middle-high.” One participant rated the feature as “low-middle” and two participants indicated the “highest” ranking in their response. The presence of the core feature of integration of content of the intensive,
ongoing professional development into daily school life was not as strongly perceived as the presence of the core feature of active learning.

The core feature of Coherence was assessed through the third question of the end of program questionnaire. Question three inquired how well the instructor connected the content of the intensive, ongoing professional development program with other professional learning. The range of responses spread across three rating categories. No participant (N=9) rated the presence of the core feature of coherence with the “lowest” rating. The rating of “low-middle” was indicated by three participants and the rating of “middle-high” was recorded by four participants. Two participants rated the presence of the core feature of Coherence with the “highest” rating. The presence of the core feature of Coherence in the intensive, ongoing professional development was not as strongly perceived as the presence of the core feature of Active Learning. Coherence was perceived as present more so than the core feature of Focus on Content Knowledge or the integration of content of the intensive, ongoing professional development into daily school life.

Participants were asked to rate the presence of the core feature of Public Examination of Practice, also known as discussions, through question four of the end of program evaluation. The participants (N=9) rated how well the instructor facilitated discussions among the teachers in the intensive, ongoing professional development program with responses across three rankings. One participant rated the presence of Public Examination of Practice as “low-middle.” The ranking of “middle-high” was selected by three participants and five participants chose the ranking of “highest” to indicate the perceived presence of the core feature. The rank of “lowest” was not selected by any of the participants (N=9). The core feature of Public Examination of Practice was perceived to a higher degree than the core features of Coherence and Connection to
Daily Practice. The core feature of Active Learning was perceived to a greater degree than the core feature of Public Examination of Practice.

On a four point Likert scale with one equating to the “lowest” rating and four equating to the “highest” rating, participants were asked to rate the presence of the core features of effective professional development. The rankings between the “highest” and “lowest” equated three to “middle-high” rating and two to a “low-middle” rating. The core feature of Active Learning was perceived as present, by all participants (N=9), with “middle-high” and “highest” ratings. Public Examination of Practice, another core feature of effective professional development, was perceived as present by eight participants (N=9) with ratings of “middle-high” and “highest.” The core feature of Coherence was perceived present with rating of “middle-high” and “highest” ratings by six participants (N=9). Focus on Content Knowledge, a core feature of effective professional development was perceived present with ratings of “middle-high” and “highest” ratings by five of the participants (N=9).

**Open-ended questions.** Open-ended questions were included on the end of program evaluation and the end of program questionnaire to learn teacher perception of the presence of the core features in the intensive, ongoing professional development program. Nine participants responded to two questions on the end of program questionnaire (see Table 16 and Table 17). Seventeen teachers answered the open-ended question on the end of program evaluation that asked participants to offer one suggestion to improve the facilitation of the intensive, ongoing professional development (see Table 18).

On the end of program questionnaire the first open-ended question asked participants (N=9) perception of the best feature of the intensive, ongoing professional development. Seven teachers responded to the prompt in a phrase or sentence. Two teachers responded with the key
phrases of “inquiry based learning techniques” (T4) and “it made me think” (T10) aligning with the core feature of Active Learning. Two participants indicated the core feature Focus on Content Knowledge as the best feature of the intensive, ongoing professional development. The phrases “the emphasis on conceptualization (T9) and “the great tactics for teaching my students some challenging skills!” referred to concepts taught within the program. No participants (N=9) described the core feature of Coherence or the connection to other professional learning in their response. The core feature of Public Examination of Practice was indicated by one participant through the response “being able to network and socialize with peers” (T2). Two respondents expressed that the instructor as the best feature of the course with phrases “the instructor was approachable and easy going” (T5), and “Jason was knowledgeable.” Responses about the instructor were categorized as “other.”

The second open-ended question on the end of program questionnaire asked participants’ (N=9) the least liked feature of the intensive, ongoing professional development program. Seven teachers responded to the prompt with a phrase or sentence (see Table 17). The core feature of
Table 17

Perceived “Worst” Feature of Professional Development Program

<table>
<thead>
<tr>
<th>Core Feature</th>
<th>Active Learning</th>
<th>Focus on Content Knowledge</th>
<th>Coherence</th>
<th>Public Examination of Practice</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Key Words</td>
<td>Content</td>
<td>Make information pertinent and relevant</td>
<td>Math disability and asking for help from participants</td>
<td>Distance and Homework</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Didn’t apply to elementary</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Not much I could use</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(N=7)

Active Learning was not indicated as a least liked feature, by the participants (N=7). Four participants referenced the core feature of Focus on Content as the least liked with the statements “The content was not user friendly nor did it transfer to actual strategies you could use in the classroom” (T5) “the ability to take the information and make it pertinent and relevant in a standardized fashion” (T3), “I learned some strategies for helping kids, but it was geared towards what I would consider to be my own mathematical learning.” (T4), and “I did not feel the class gave me much I could use with my students” (T8). The core feature of Coherence, or connection to other professional learning, was not indicated by any participant (N=17) in their response to the open-ended question. One participant described the core feature of Public Examination of Practice as the least liked in the response “I have a math disability and I felt uncomfortable with some of the participants and their reactions when I would ask them for help” (T9). The
responses of “the distance I had to travel” (T4) and “I enjoyed it all except the homework” (T7) did not align to a core feature of effective professional development and were categorized as “other.”

The end of program evaluation included an open-ended question for participants (N=17) to make one suggestion for the facilitation of the intensive, ongoing professional development program. Responses that did not align to the core features of effective professional development were categorized as “other.” The phrases “smaller binder” (T2), “snacks” (T3), “I thought Jason was an outstanding instructor” (T5), “I enjoyed the class” (T7), “I thought it was very beneficial the way it was” (T10), “Don’t patronize us by telling us you don’t understand” (T17), and “very good instruction” (T18) aligned to the category of “other.” In a suggestion for the instructor, two participants referred to the core feature of Active Learning with the phrases “use manipulatives during the class period for the sessions that use them” (T4) and “more practice with manipulatives during the class session” (T6). The core feature of Focus on Content Knowledge was suggested by five participants through the comments “to explain some of the difficult concepts-more direct teaching” (T15), “I was hoping for more strategies-theories on methods to teach math” (T14), “have concrete examples of the various topics that would make those topics relatable to kids” (T8), “if there are any other ideas he could suggest for implementation of concepts and ways to improve instruction for better understanding” (T9), and “more practice problems/homework or questions that would make us think about how to apply content to the classroom” (T13). One teacher referenced Public Examination of Practice with the suggestion of “I liked working in small groups however at times I would have liked more large group discussions when small groups were struggling” (T11). None of the participants (N=17) made a suggestion related to the core feature of Coherence. Three participants wrote a second sentence
or phrase in their suggestion for the instruction. Those secondary responses aligned to the core features of either Focus on Content Knowledge with the phrases of “the concepts (some) were quite abstract and could be difficult to grasp for kids” (T8), and “I was hoping to get more strategies to use with struggling learners” or “other” with the comment “I don’t like having to send work away for college credit” (T7). Participants T8 and T7 added a third sentence to their suggestion that further explained their secondary response.

Table 18

*End of Program Evaluation Suggestions*

<table>
<thead>
<tr>
<th>Frequency of Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>One Suggestion</td>
</tr>
<tr>
<td>Primary Response</td>
</tr>
<tr>
<td>Key Words</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

| Secondary Response     | Concepts quite abstract | More strategies | College credits |
| Key Words              |                            |                |                 |
|                        | 0                           | 2              | 0               |

(N=17)
The third guiding question of this study inquired how did teachers of grades K-8 perceive the presence of the core features of effective professional development in the intensive, ongoing professional development. Through multiple data collected from the end of program questionnaire and end of program evaluation, participants of this study perceived the features of Active Learning, Focus on Content Knowledge, and Public Examination of Practice as present in the intensive, ongoing professional development. The core feature of Active Learning was rated as present with “middle-high” and “highest ratings by all participants (N=9). Active Learning was referenced in the open-ended responses by two participants and two participants suggested spending more class time using the manipulatives. Focus on Content Knowledge was perceived present by all participants (N=9) with ratings spanning from “lowest” to “highest” in the close-ended responses. The open-ended responses related to a Focus on Content Knowledge indicated a similar span of perceived presence in the program as four participants listed the core feature as the most useful concept, as the worst aspect of the program by four participants, and was included in suggestions for the instructor by five participants. Public Examination of Practice was perceived as present by the participants with eight participants assigning the ratings of “middle-high” and “highest” and at least one participant included the core feature as the best part of the program, as the worst part of the program, and as a suggestion for the instructor. Coherence was perceived as present through the data collected via close-ended responses on the end of program questionnaire with ratings ranging from “low-middle” to “highest.” The core feature of Coherence was not perceived as present through the data collected via open-ended responses. In open-ended responses the participant responses included “other” features of the intensive, ongoing professional development that were not among the identified core features of
effective professional development. The “other” features referenced the instructor, travel
distance, seating arrangements, college credit for work and snacks.

**Summary**

This outcome evaluation study was designed to examine the impact of an intensive,
ongoing professional development program on teacher content and pedagogical knowledge, as
well as the perceived presence of the core features of effective professional development. The
research relied on data from close-ended questions, and open-ended questions from an end of
program evaluation and an end of program questionnaire, a tri-plot and pre- and post-tests for the
purpose of triangulation in order to strengthen both reliability and validity of the study.

Throughout analysis of the data, the study provided results that indicated a positive
impact on content and pedagogical knowledge for nearly all participants, as well as a perceived
presence of the core features of effective professional development in the intensive, ongoing
professional development. The pre- and post-tests provided results indicating that collectively
the participants improved in Knowledge Level scores, Subcategories scores and Total Scores.
The elementary teachers improved to a greater extent with content knowledge than pedagogical
knowledge and the middle school teacher improved to a greater extent with pedagogical
knowledge than content knowledge. The tri-plot provided results revealing that on average
participants perceived a greater increase in content knowledge than pedagogical knowledge. The
close-ended questions on the end of program questionnaire indicated a perceived presence of
each from the core features of effective professional development. The open-ended questions
from the end of program questionnaire displayed a perceived presence of three of the core
features of effective professional development; Active Learning, Focus on Content Knowledge,
and Public Examination of Practice.
Chapter 5: Discussion

Summary of the Study

This outcome evaluation study examined the impact of an intensive, ongoing professional development program on teacher content and pedagogical knowledge as well as the perceived presence of the core features of effective professional development. The success of educational reform initiatives is dependent on an increase in teacher content knowledge and pedagogy through effective professional development. Teacher content and pedagogical knowledge as well as teacher perceptions were elicited through multiple measures of data collection, which provided the triangulation necessary to increase the validity of this study. Reliability is shown through the presentation of the methodology, data collection and analysis.

Significant research has indicated that professional development should be intensive, ongoing, and connected to practice. Intensive professional development, especially when presented in context with direct applications of knowledge to teachers’ planning and instruction, has a greater chance of influencing teaching practices and, in turn, leading to gains in student learning (Knapp, 2003; Cohen & Hill, 2001; Desimone, et al., 2002; Garet, et al., 2001; McGill-Franzen, et al., 1999; Supovitz, Mayer & Kahle, 2000; Weiss & Pasley, 2006). Professional development that is aligned to school improvement goals, school resources, curriculum maps and data systems is more effective than learning that is disconnected to school reform efforts or changes in progress at the school, district, or state level (Snow-Renner & Lauer, 2005; Carpenter, 1989; Cohen & Hill, 2001; Garet, et al., 2001; Desimone, et al., 2002; Penuel, Fishman, Yamaguchi & Gallagher, 2007; Saxe, Gearhart & Nasir, 2001; Supovitz, Mayer & Kahle, 2000). Building productive working relationships among colleagues teaching the same content or grade-level can improve consistency of instruction, sharing of practices, and collaborative problem
solving (Elmore & Burney, 2007; Cohen & Hill, 2001; Garet, et al., 2001; Penuel, Fishman, Yamaguchi & Gallagher, 2007; Supovitz, Mayer & Kahle, 2000). Teachers value professional development when it provides “hands-on” opportunities to build knowledge of academic content and how to teach their students (Desimone, et al., 2002). National teacher self-reported data gathered on the prevalence of the (aforementioned) six characteristics and teacher perception of the effect on their knowledge, skills, and classroom practices revealed that most district supported professional development activities do not have the six high-quality characteristics (Desimone et al., 2002). Seminal research conducted by Desimone et al., (2002) concluded that the key features of professional development (i.e. reform type, duration, collective participation, active learning, coherence and content focus), could be hypothesized as effective and were related to increases in teachers’ self-reported knowledge and skills and changes in teacher practice.

The purpose of this outcome evaluation study was to determine the impact of an intensive, ongoing professional development program focused on the development of teacher content knowledge, pedagogical knowledge, as well as assess their perception of the presence of core features of the program. The study entailed multiple methods of data collection, i.e., end of program evaluation, end of program questionnaire, and a pre- and post-test. The pre- and post-test, obtained from the University of Louisville Center for Research in Mathematics and Science Teacher Development, was the primary instrument for quantitative data collection. The end of program evaluation and end of program questionnaire provided additional quantitative data and added the voices of the participants with qualitative data to understand the social phenomenon of the professional development program as implemented. Seventeen teachers of grades K-8 mathematics were asked to complete a twenty-item pre-test and post-test concerning their
content and pedagogical knowledge in the mathematical strand Numbers and Operations. The items measured participants’ ability to solve mathematical problems and explain their reasoning. Areas assessed aligned to the categories of Knowledge Level I: Memorized/Factual Knowledge; Knowledge Level II: Conceptual Understanding; Knowledge Level III: Reasoning/Problem Solving; and Knowledge Level IV: Pedagogical Content Knowledge. These categories included the subcategories of Whole Numbers, Rational Numbers, Integers, Operations/Computation and Number Theory. The pre-test and post-test results were reported as raw scores and compared using a t-test statistical analysis and reviewed for significant individual participant differences as well. The pre-test and post-test was given just prior to and after participants completed a ten-week (ongoing) professional development program focused on the mathematical strand of Numbers and Operations (intensive).

At the conclusion of the professional development program, participants completed another version of the Diagnostic Teacher Assessments in Mathematics and Science in Numbers and Operations as the post-test. All participants completed a nine-item end of program evaluation consisting of four Likert scale close-ended questions, two open-ended questions and three additional close-ended questions reported on a continuum. The Likert rating scale on the end of program evaluation consisted of four degrees, with 1 as the lowest and 4 as the highest, to probe teachers’ perception of the instructor’s facilitation of the intensive, ongoing professional development. The end of course evaluation questions were also reported on a continuum-seeking teachers’ perception of learning, according to the categories of subject, teaching, and learning. Nine of the participants also completed an end of program questionnaire that consisted of three open-ended items and four Likert scale items. The Likert scale items on the end of program questionnaire probed teacher perception of the presence of the core features of an
effective professional development program. The professional development providers facilitated the assessment measures in order to maintain the anonymity of participants.

**Summary of the Findings**

The results of this study were guided by three research questions, which examined the impact of an intensive, ongoing professional development program on teacher content and pedagogical knowledge, as well as the perceived presence of the core features of effective professional development.

The results of the study indicated that participants’ engagement in the studied intensive, ongoing professional development positively impacted their content and pedagogical knowledge.

1. Participation in this intensive, ongoing professional development program increased teacher content knowledge.

2. Participation in this intensive, ongoing professional development program increased teacher pedagogical knowledge.

3. Participants’ perception of the core features of effective professional development varied between open-ended and close-ended responses.

*Participation in this intensive, ongoing professional development program increased teacher content knowledge.* The first research question inquired about the impact of an intensive, ongoing professional development program on K-8 teacher mathematical content knowledge. The results of this study suggested that K-6 teachers’ content knowledge increased significantly in Knowledge Level I: Memorization/Factual and Knowledge Level III: Reasoning/Problem Solving. The grades 7-8 teachers increased in Knowledge Level II: Conceptual Understanding and Knowledge Level III: Problem Solving/Reasoning. K-6 teachers improved in all elementary subcategories: Whole Numbers, Operations/Computation and
Number Theory. The grades 7-8 teachers increased in all middle school subcategories: Whole Numbers, Rational Numbers, Integers and Number Theory. Teachers who answered all parts of the multi-step questions on the pre- and post-test by showing all mathematical calculations and briefly explaining thinking, increased from pre- to post-test. Teachers who did not respond to every part of every question decreased in their score for content knowledge from pre- to post-test.

The impact of the intensive, ongoing professional development program on teacher content knowledge was further supported by the findings within the end of program evaluation and end of program questionnaire. The results of the end of program evaluation suggested that K-8 teachers’ perception of professional growth as a result of participation in the program was attributed to the dimension of Learning of Mathematics (cognition) five percent more than the dimensions of mathematics teaching (pedagogy) and eleven percent more than mathematics content. The results of the end of program questionnaire suggested teachers’ perceived Public Examination of Practice (discussion) and Active Learning (hands-on), two of the core features of effective professional development, as present in the intensive, ongoing professional development program with ratings of “middle-high” and “highest” by eighty-nine percent of those surveyed. The core feature of Focus on Content (connecting learning to daily school routines) was perceived to the degree of “middle-high” and “highest” by fifty-five percent of those questioned. In responses to open-ended questions teachers equally cited the best features of the professional development program as Active Learning, Focus on Content Knowledge and the instructor. In the open-ended question responses, teachers denoted the connection of the course content to their daily school routines (Focus on Content Knowledge) as the worst feature of the intensive, ongoing professional development program.
Teachers met for three hours a week for a ten-week period to engage in interactive problem solving with math manipulatives, small group discussion, and lesson study specific to the mathematical strand Numbers and Operations. The increase in teacher content knowledge from pre- to post-test suggests that the core features of “Active Learning” and “Public Examination of Practice” contributed to the increase. Learning of Mathematics (cognition), as recorded on the tri-plot, was perceived by the participants as contributing to the increase in content knowledge. Teachers’ suggestions that connections were not clearly made to daily school routines by the instructor indicated that a Focus on Content contributed to the increase in content knowledge to a lesser degree than the aforementioned core features of effective professional development.

Study results indicate that teacher content knowledge in the mathematical strand Numbers and Operations increased following participation in an intensive, ongoing professional development program. These results suggest that intensive, ongoing professional development programs, which include the core features of Active Learning, Public Examination of Practice and a Focus on Content impact teacher content knowledge. Teacher content knowledge increased along three knowledge types, Knowledge Level I: Memorized/Factual; Knowledge Level II: Conceptual Understanding, and Knowledge Level III: Reasoning/Problem Solving. Improvement in Level II or Level III knowledge suggests that teachers are deepening their knowledge of mathematics content beyond memorized/factual knowledge and Conceptual Understanding to Reasoning/Problem Solving as a result of participation in the intensive ongoing professional development. K-8 teachers perceived that the presence of the core feature of Focus on Content Knowledge was spread across all four degrees; lowest, low-middle, middle-high and
highest indicating a wide variance in understanding how the professional development program connects learning to daily school routines.

**Participation in an intensive, ongoing professional development program increased teachers’ pedagogical knowledge.** The second guiding question inquired about the impact of an intensive, ongoing professional development program on K-8 teacher pedagogical knowledge. The study indicated a significant increase in teacher pedagogical knowledge as a result of participation in the ten-week program. Teachers who completed all questions as well as explained how to help a student understand mathematical misconceptions increased in pedagogical knowledge.

The impact of the intensive, ongoing professional development program on teacher pedagogical knowledge was further supported by the findings within the end of program evaluation and end of program questionnaire. The results of the end of program evaluation suggested that K-8 teacher perception of professional growth, as a result of participation in the program, was attributed to the dimension of the teaching of mathematics (pedagogy) five percent less than the learning of mathematics (cognition) and eleven percent more than subject knowledge (content knowledge). In response to the open-ended questions eighty-three percent of the K-8 teachers identified the best feature of the professional development program as Pedagogical Knowledge. Using terminology such as manipulatives, models, hands-on, visual models, new ways of understanding, problem solving, instructional strategies, videos, and conceptualization, teachers referenced two core features of effective professional development—Active Learning and Focus on Content. In the open-ended question responses, teachers denoted the connection of the course content to their daily school routines (Focus on Content Knowledge), as the worst feature of the intensive, ongoing professional development program.
The results suggest that K-8 teachers did not view the Active Learning through the use of manipulatives, models, problem solving, videos, etc., of the intensive, ongoing professional development as a way to connect program content to their daily school routines (Focus on Content Knowledge).

**Participants’ perception of the core features of effective professional development varies between open-ended and close-ended responses.** The third guided question inquired how K-8 teachers perceived the presence of the core features of effective professional development in the intensive, ongoing professional development. Data from the study revealed participants perceive the core features of effective professional development as present in the ten-week program. The close-ended questions on the end of program questionnaire specifically named the core features of effective professional development. The open-ended questions on the end of program questionnaire and end of program evaluation required the teachers to identify components of the intensive, ongoing professional development in their response. The K-8 teachers perceived the core feature of Active Learning as present to a higher degree than Coherence, Public Examination of Practice and Focus on Content Knowledge in their responses to the close-ended questions. In the teachers open-ended responses teachers referenced the core features of Active Learning and Focus on Content Knowledge to a greater degree than Public Examination of Practice as the best feature of the program. Focus on Content was the most referenced core feature in response to the open-ended question seeking the least-liked feature of the intensive, ongoing professional development program. The findings suggest a misunderstanding of the core feature of Focus on Content when forty-four percent of the K-8 teachers request ways to make the content more relevant and pertinent to their classroom, yet cite the feature of Active Learning as the best feature of the program.
Summary. The study centered on three guiding questions examining the impact of an intensive, ongoing professional development program on teacher content and pedagogical knowledge, as well as the perceived presence of the core features of effective professional development. The study revealed data indicating increases in teacher content and pedagogical knowledge and the K-8 teachers perceived the core features of effective professional development as present in the intensive, ongoing professional development program.

Findings in Relation to the Theoretical Framework

This study was informed through the theoretical framework of effective professional development that has evolved in over two decades of data gathered through the Title II B of the Elementary and Secondary Education Act (ESEA) Math and Science Professional Development Grant program. Under the ESEA grant guidelines professional development must include: (1) sponsorship through a partnership between a local educational agency and institute of higher education; (2) the structural features of contact hours, collective participation, and sustained time; and (3) the core features of focus on content knowledge, active learning, coherence, and public examination of practice. The presence of the aforementioned sponsorship, structural features and core features result in the outcomes of enhanced knowledge and skill. Each of these features served as a lens to investigate the implications of the intensive, ongoing professional development in the mathematical strand of Numbers and Operations.

Partnership between LEA and IHE. The guidelines of the ESEA, Title II B Math and Science Partnership grant require the local educational agency (LEA) to partner with an Institute of Higher Education. The IHE is expected to enhance the partnership activities by providing faculty to plan, present, and evaluate professional development, or provide onsite support for teachers during the school year. For the purposes of this study, a regional educational agency
coordinated the partnership between two local educational agencies, institutes of higher education and a national level professional development provider. Both the regional education association and the local education association distributed a professional development needs assessment survey, provided student achievement data to narrow down the focus of the professional development content, shared the professional development information with elementary and middle school math teachers, and collected the end-of-course survey. The National Institute Advanced Teaching and Learning delivered the content provided by the Annenberg Institute and Colorado State University as well as the end-of-course evaluation. The University of Louisville’s Center for Research in Mathematics and Science Development provided and scored the Diagnostic Teacher Assessments in Mathematics and Science pre- and post-tests, which measured teacher content and pedagogical knowledge. On the end of program questionnaire two participants indicated the best feature of the intensive, ongoing professional development was the instructor, with the phrases “the instructor was approachable and easy going” and “Jason was knowledgeable.” The instructor is a professor at a Pennsylvania IHE, an instructor for the University of Colorado, and senior facilitator of the National Institute of Advanced Teaching and Learning. The intensive, ongoing professional development conducted in this study was sponsored through a dynamic partnership between local education associations, a regional education association, two institutes of higher education, and a national professional development provider.

**Structural features.** Structural features of effective professional development include Contact Hours, Collective Participation and Sustained Time. The duration of professional development impacts the opportunity for in-depth discussion of content, student misconceptions, and pedagogical strategies. For example, professional development activities extended over time
allow teachers to test new pedagogies and obtain feedback. Professional development designed for groups of teachers from the same school, department or grade-level promote discussion of concepts, skills, problems that arise during professional development experiences, curricular materials, course offerings and assessment requirements. Collective Participation in professional development designed for groups of teachers may sustain changes in practice, develop a shared professional culture with common understanding of goals, methods, problems and solutions as well as allot for the integration of learning into other aspects of instruction. Contact Hours, Collective Participation and Sustained Time are required structural features of the Title II B Math and Science Partnership grant. The structural feature of Sustained Time is addressed by the Math and Science Partnership grants through a requirement of 30 contact hours in a week-long summer intensive professional development session plus twelve additional contact hours during the school year. To measure the structural feature of Collective Participation in professional development the seminal researchers of the Math and Science Partnership grants asked whether the “activity was designed for all teachers in a school, or a set of schools, or all teachers in the teacher’s department or grade level (Garrett, Porter, Desimone, Birman, & Yoon, 2001).” For the purposes of this study the Contact Hours were aligned to a three-credit college course, or thirty seat hours sustained over a ten-week period. Middle school and elementary teachers of mathematics from local educational agencies within the regional educational agency’s service area created a Collective Participation of teachers of mathematics to discuss content, pedagogies and implementation of concepts.

**Core features.** What teachers learn during professional development activities and how that content is learned are described through the core features of professional development. Through the examination of Title II B Math and Science Partnership grants Garrett, Porter,
Desimone, Birman, & Yoon (2001), clarified a Focus on Content Knowledge as a “focus on specific content and how students learn that content as a central feature of high-quality professional development. In this the study, the professional development focused on the content within the mathematical strand Numbers and Operations. The participants were instructed in the concepts of whole numbers, rational numbers and integers as well as how students learn this content. The Diagnostic Teacher Assessment in Mathematics & Science pre- and post-tests as well as the end of program evaluation and end of program questionnaire were used to measure the core feature of focus on content. On the end of program evaluation and end of program questionnaire open ended and closed ended items revealed participant perception of the presence of the core feature of focus on content. Participants referred to the focus on content as the best feature of the intensive, ongoing professional through comments on the end of program questionnaire such as “the emphasis on conceptualization,” “great tactics for teaching my students some challenging skills,” and “dividing fractions using a common denominator.” Other participants noted the focus on content as the least liked feature with comments that included “the content was not user friendly nor did it transfer to actual strategies you can use in the classroom,” “the ability to take the information and make it pertinent and relevant in a standardized fashion,” and “the content was not user friendly nor did it transfer to actual strategies you could use in the classroom.” On the end of program evaluation, by five participants made suggestions related to Focus on Content. The aforementioned participants suggested a need “to explain difficult concepts,” “for more strategies to teach math,” “for ways to improve instruction and to apply content to the classroom.” The end of program questionnaire also showed a wide variance in the perceived presence of a focus on content with the results ranging from the lowest possible to the highest possible rankings. The pre- and post-test results
revealed a similar pattern with a wide range of total score differences (see Table 19). Four participants lost from two to as many as sixteen points, while ten participants gained from four to as many as thirteen points. According to the participants’ responses as well as post-test results, a Focus on Content was present in the intensive, ongoing professional development.

Table 19

<table>
<thead>
<tr>
<th>Participant</th>
<th>Difference</th>
<th>-9</th>
<th>-6</th>
<th>-3</th>
<th>-2</th>
<th>-1</th>
<th>0</th>
<th>+1</th>
<th>+4</th>
<th>+5</th>
<th>+6</th>
<th>+10</th>
<th>+12</th>
<th>+13</th>
</tr>
</thead>
<tbody>
<tr>
<td>T0448</td>
<td>T2431</td>
<td>T6796</td>
<td>T9354</td>
<td>T9611</td>
<td>T0612</td>
<td>T3809</td>
<td>T386</td>
<td>T8180</td>
<td>T2539</td>
<td>T6861</td>
<td>T0493</td>
<td>T2006</td>
<td>T7186</td>
<td></td>
</tr>
</tbody>
</table>

The participant responses as well as the difference in scores from pre- to post-test indicate a Focus on Content in the intensive, ongoing professional development could be improved. Comparing the end of course questionnaire to the pre- and post-test scores, T2431 lost sixteen points and asked for concrete examples of applications of the concepts being discussed. T0448 lost nine points between assessments and indicated “difficulty relating the course content to what I do each day. I learned some strategies but it was geared towards what I would consider to be my own mathematical learning. I thought it would be more about how I could help the kids. I suppose it was, just indirectly.” T6796 lost three points and suggested the professional development facilitator needed “to provide actual strategies to use with struggling math students. It would be difficult for the most gifted student to use.” T8180 gained four points but “didn’t feel the instructor taught. It was more about discovering things for ourselves.”
However if I had to discover and work really hard in this course, I’m not sure how I could realistically apply it to kindergarten.” T2006 thought the instructor provided the most effective learning environment” and gained twelve points. T2006 also noted “that not all of the participants were pure math teachers. As a result those with a daily focus on only math were more advanced and tended not to be very helpful to those of us that were struggling. It might be helpful to find a way to provide the same course work but with a different grouping.” T6861 and T0612 did not lose points from pre- to post-test and did not make suggestions to improve the content focus of the intensive, ongoing professional development. Eleven participants did not complete the end of program questionnaire and they did increase the total score from pre- to post-test. The available open ended responses paired with the difference in scores clarify participant perception of the presence of the core feature a focus on content. The focus on content for participants whose professional responsibilities reach beyond teaching math was not the same as those participants who only teach math. T2431 is a middle school principal who has no teaching responsibilities. T0448 has a professional responsibility that spans grades two through four and covers subjects beyond math as noted in comments to open ended questions.

In response to questions about typical trends from pre- to post-test, Dr. Jane Jones of the University of Louisville and the Center for Mathematics and Science Teacher Development shared three observations: (1) Post-tests are often weaker than pre-test when the post-test is given as an “out the door,” end of workshop task; (2) Participants are in a hurry to leave and they scribble answers, which are often incomplete. In other instances it is clear that from the brevity of elapsed time taken to complete the test or other comments on the tests, the testing conditions were less than ideal; (3) Another pattern is seen in the duration of the professional learning. On intensive, short-term workshops there is an improvement in post-tests but a decline
in post-post-test results given as a later follow-up activity. “Teachers are like our students, they
do well when all the new content is fresh in their minds, but unless they are using all that new
content every day, they quickly forget what they learned.” Dr. Jones stressed each learning
situation is different and the professional development organizers are the ones who can make a
judgment about the degrees of improvement (Jones, 2014). For the purposes of this study, the
post-test was administered during the last session of the ten-week professional development.
The timing of the pre-test as well as the length of the intensive, on-going professional
development may have impacted the core feature of a Focus on Content. The eleven participants
who answered all questions as completely as possible - showed all of their work in response to
items and briefly explained their thinking on all items, increased their total score from pre-test to
post-test. Participants who did not complete all items or failed to briefly explained their thinking
on all items scored fewer points between the pre-test and post-test.

A second core feature of effective professional development concerns active engagement
in meaningful discussion, planning and practice. Active Learning could also include observation
and being observed, planning classroom implementation, reviewing student work, presenting,
leading, and writing. The types of Active Learning described were used to categorize participant
descriptions of what occurred within the intensive, ongoing professional development. On an
open ended question from the end of program evaluation participants cited the use of
“manipulatives,” “models,” “hands-on activities,” “visuals,” and “Venn diagrams” to describe
active learning in the intensive, ongoing professional development. On the close-ended question
from the end of program questionnaire, Active Learning was scored at either the middle-high or
the highest ranking by all the participants. By the design of the instructor, the participants were
seated in small groups around tables to promote discussion and each of the participants received
a kit of math manipulatives. The manipulatives were used during the intensive, ongoing professional development and for the teachers to use in their classrooms after the 10 week course. The instructor and the participants concur that the core feature of Active Participation was present in the intensive, ongoing professional development to middle-high or high degree.

The extent to which professional development activities are perceived by teachers to be part of a coherent program of teacher learning is the third core feature of effective professional development. Professional learning that connects with goals, other professional learning and aligns with state standards and assessments creates Coherence. The participants of the intensive, ongoing professional development were teachers of elementary and middle school mathematics, however their professional responsibilities varied. As T2006 noted, “not all of the participants were pure math teachers. The participants included a middle school administrator, without instructional responsibilities, who hoped to use the content of the intensive, ongoing professional development with the teachers in his school. Seven participants were responsible for teaching math as well as other core subjects and eight participants taught strictly math. T2006 observed…“As a result those with a daily focus on only math were more advanced and tended not to be very helpful to those of us that were struggling.” On the end of program questionnaire, participants indicated Coherence was present in a range from the low middle to the highest degree. The intensive, ongoing professional development was designed for teachers of kindergarten through eighth grade mathematics to address the core feature of Coherence. The Number & Operations intensive, ongoing professional development was the first offering in what was to be a series of six courses. Through a series of intensive, ongoing professional development “courses” Coherence would be increased as participant learning builds upon past and future professional learning in mathematics as well as through the exploration of the
Pennsylvania Core Standards. As T2006 noted “it might be helpful to find a way to provide the same course work but with a different grouping.”

When teacher educator change is one goal of professional development, devices such as post-program surveys, interviews, or data from a participant’s own teaching, selected mathematical tasks and assessments, or classroom observation are utilized to open participant’s practices to discussion and examination of those practices in a more public way (Tyminski, Ledford, & Hembree, 2010). Public Examination of Practice is the fourth core feature of effective professional development and was built into the intensive, ongoing professional development through class assignments, video observations of math lessons, class discussion, and end of program surveys. On the end of program evaluation participants indicated that they learned more about the learning of mathematics, than pedagogy and subject knowledge. Statements on end of program evaluation such as the following reflect cognition (learning of mathematics) and pedagogy (teaching of mathematics) (See Table 20).

The majority of participants rated the presence of the core feature of Public Examination of Practice to the middle-high or highest degree. Combining the closed ended responses with open ended responses reveal ways Public Examination of Practice could be improved in the intensive, ongoing professional development. Two participants suggested cognition or the learning of math could be improved by using the math manipulatives during the class session before use in an out-of-class assignment. Another participant commented that they “liked working in small groups however at times I would have liked more whole group discussion when small groups were struggling.” The comments from the open ended questions, as well as the closed ended questions demonstrate the presence of the third core feature of professional development as well as suggestions for improvement.
Table 20

Participants’ Public Examination of Practice

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>It was extremely helpful to see new ways of understanding multiplication and division other than the standard algorithm.</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Problem solving – the steps, processes, and types of chapter on it and class gave whole new perspective.</strong></td>
<td></td>
</tr>
<tr>
<td><strong>The area models were most useful for multiplication of fractions.</strong></td>
<td></td>
</tr>
<tr>
<td><strong>The videos of others completing the task were useful as well.</strong></td>
<td></td>
</tr>
<tr>
<td><strong>The use of manipulatives for the four basic operations and the understanding of fractions.</strong></td>
<td></td>
</tr>
<tr>
<td><strong>The last concept – fractions, ration, and percent</strong></td>
<td></td>
</tr>
<tr>
<td><strong>I found the use of manipulatives to make math more concrete to be the most useful.</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Facilitate discussions among my students</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Allow students to explore and experience math as a fun learning experience</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Move students from concrete through understanding (with visuals, manipulatives) to abstract</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Hands-on- students need to understand the concept to really learn it.</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Number theory concepts with visual models</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Teaching greatest common factor and least common factor using Venn diagrams – love it!</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Dividing factions using a common denominator</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Using manipulative to teach math concepts bases (4 and 5 as opposed to base 10).</strong></td>
<td></td>
</tr>
<tr>
<td><strong>The use of different models and manipulatives to explain math concepts.</strong></td>
<td></td>
</tr>
</tbody>
</table>

**Outcomes.** Through the partnership with IHEs, along with the presence of structural features of effective professional development as well as the core features effective professional development, the outcome expected is enhanced knowledge and skill. Enhanced knowledge and
skill was measured through the Diagnostic Teacher Assessment of Mathematics and Science pre- and post-test. For each assessment, item participants were expected to explain their thinking as a demonstration of Knowledge Level III: Reasoning or Problem Solving. Collectively the participants increased by thirteen points from pre- to post-test. Individually, participants lost or gained from pre- to post-test in direct relation to the number of questions on which they explained their mathematical reasoning. In other words, if the participants diligently explained their thinking on each item, their score increased. If the participant left items without an explanation their score decreased from pre- to post-test. For five of the assessment items, the explanation of thinking required participants to identify the “student’s” misconception and show how to correct the misconception. This level of thinking equates to Knowledge Level IV: Pedagogy. Collectively the participants increased by twenty-two points in pedagogy from pre- to post-test. As with Knowledge Level III, if the participants attempted to explain their thinking on all Knowledge Level IV items their score increased from pre- to post-test. From the lens of Webb’s Depth of Knowledge Level III and IV, the highest depths of knowledge, the outcome of enhanced knowledge and skill can be examined with Dr. Jane Jones’ observations in mind. If the post-test is given at the end of the professional development teacher motivation and effort to answer all questions completely may be impacted.

Discussion of the Findings in Relation to the Literature

The findings in this study have strong connections with the literature and research presented in Chapter II. The literature review focused on six main themes to inform this study:

1. Teachers’ Mathematical Content Knowledge
2. Teachers’ Pedagogical Content Knowledge
3. Society’s Expectation for Effective Professional Development
4. Principles of Effective Professional Development

5. Historical Perspective of Professional Development

6. Ongoing Professional Development

Connections between the findings of this study to each of these six areas are reviewed below.

**Teachers’ mathematical content knowledge.** What do teachers need to know about their subject area? Grossman, et.al. (1989) claim some of what teachers need to know about their subject overlaps with the knowledge of scholars in the discipline. In the realm of mathematics education, mathematical content knowledge is some of what teachers of mathematics need to know is how their subject area overlaps with the knowledge of mathematicians. Teachers also need to understand math in ways to promote learning to help student acquire knowledge within the subject area of mathematics (Grossman, et. al., 1989).

Shulman (1986) presented the notion that content knowledge needed for teaching also involves knowing “why something is so, not just that it “is” so.” In mathematics this means more than being able to simply compute. Shulman’s notion is better understood through the lens of Webb’s Depth of Knowledge (1997). Depth of Knowledge 1: Recall & Reproduction equates to the ability to calculate, measure, apply a rule or apply an algorithm while Depth of Knowledge 2: Skills & Concepts aligns to the ability to explain the meaning of a concept. Knowing ‘why something is so…” is Depth of Knowledge 2: Skills & Concepts. Depth of Knowledge 3: Short Term Strategic Thinking requires the cognitive capability of explaining and supporting the explanation with evidence. Teachers who are able to promote learning to help students acquire knowledge within the subject (Grossman, et. al., 1989) are able to operate at Depth of Knowledge 2 and Depth of Knowledge 3. Heaton (2000) described mathematics understanding as equivalent to Depth of Knowledge 3: Short Term Strategic Thinking with phrasing such as
“the dynamic, constructed, and reconstructed process of sense making by the learner” and “learning to represent or communicate mathematical ideas or interpret mathematical representations through the use of language, diagrams, pictures, manipulatives, and other tools.”

When planning instructional units to support student learning, where students construct and reconstruct mathematics, a teacher is employing cognitive capabilities aligned to Depth of Knowledge 4: Extended Thinking. Teachers operate at Depth of Knowledge 3 and Depth of Knowledge 4 when they communicate mathematical ideas to others and plan instruct in which students construct and reconstruct mathematics.

For the purposes of this study, mathematical content knowledge was connected to the core features of effective professional development. Intentionally the core features of a Focus on Content, Active Learning, Coherence and Public Examination of Practice were addressed in the design of the intensive, ongoing professional development. Through a sustained focus on the content and skills associated with the mathematical strand of Numbers and Operations (which included computation, problems solving, the use of manipulatives to demonstrate abstract concepts, class discussion and video observations of teachers implementing specific strategies), the participants developed mathematical content knowledge. Participants were asked to demonstrate all four depths of knowledge through the aforementioned professional development activities. Solving mathematical problems such as “Which of the following number is the closest in value to 0.56” is a procedural skill and equivalent to Depth of Knowledge 1: Recall & Reproduction. Depth of Knowledge 2: Skills & Concepts was employed by participants when asked to “explain your thinking.” To respond to the combined prompts, “Which student is correct?” and “explain your thinking” participants accessed the cognitive capabilities of the Depth of Knowledge 3: Short Term Strategic Thinking. In order to “describe an instructional
strategy that will help support the incorrect student and correct any misconceptions” participants needed to apply the extended thinking skills of Depth of Knowledge 4.

**Mathematical pedagogical content knowledge.** Historically in teacher education, a presumption prevails that pre-service teachers develop subject matter content knowledge and the knowledge of how this content is taught as a result of training and experience (Foss & Kelinsasser, 1996). Richardson (1994), Kagan (1992), as well as Brookhart and Freeman (1992) joined Ball’s (1988) call for the further examination of the influences of different kinds of teacher education experiences on participants’ knowledge and orientations toward mathematics as well as the teaching of mathematics. Content specialists do not necessarily possess the pedagogical content knowledge that teachers have (or should have), knowledge which, through using a variety of techniques or methods, transforms content per se into content for teaching (Shulman, 1986). Shulman (1996) adds, that teachers need to find

“the most useful forms of representation of the [the subject area’s] ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations-in a word, the ways of representing and formulating the subject that make it comprehensible to others” (p.9).

According to Segall (2004) teaching is the transformation of content into pedagogical forms. Mathematical Pedagogical Content Knowledge is the transformation of mathematics “into the context of facilitating student understanding through specific representations or analogies” (Shuman, 1986, p. 982) well as to understand and anticipate particular misconceptions of their students. Mathematical knowledge for teaching is significantly related to student achievement supporting the efforts to improve mathematics education in school by improving the mathematic
education of teachers (Goldhaber & Brewer, 1999; Fetler, 1999; Monk, 1994; Hill, Rowan & Ball, 2005).

For the purposes of this study the core features of Active Learning and Public Examination of Practice were intentionally included in the intensive, ongoing professional development to impact the mathematical content pedagogical knowledge of the participants. In the open-ended responses of the end of program evaluation, the participants reference Mathematical Pedagogical Content Knowledge and ways of representing the subject’s areas ideas with phrases such as those in Table 21. Table 22 displays participants’ reference to the core features of Public Examination of Practice.

Table 21

*Participants’ References to Mathematical Pedagogical Content Knowledge*

| The area models were most useful for multiplication of fractions. |
| The use of manipulatives for the four basic operations and the understanding of fractions. |
| The last concept- fractions, ratios and percentages |
| Number theory concepts with visual models |
| Teaching Greatest Common Factor and Least Common Factor using Venn Diagrams - love it! |
| Dividing fractions using a common denominator |
| It was extremely helpful to see new ways of understanding multiplication and division other than the standard algorithm. |
| The use of different models and manipulatives to explain math concepts |

*Society’s expectations for effective professional learning.* Across professions, there is increasing pressure toward for more effective, efficient, and evidence-based
Table 22

Participants’ References to Public Examination of Practice

| Problem solving - the steps, processes, and types of the chapters on it and class gave me a whole new perspective. |
| I found some new ways to help my students understand math better |
| Videos of mathematical instruction in the content area of Numbers and Operations as well as discussion of instructional strategies. |
| The videos of others completing the tasks were useful as well. |
| Hands-on students need to understand the concept to really learn it. |
| The most useful concept was to allow students to explore and experience math as a fun learning experience. Also that conceptualization is a missing key |
| Move students from concrete thorough understanding (with visuals, manipulatives) to abstract |
| Seeing the importance of these lessons will help me communicate with teachers. |

practices that deliver improved outcomes (Garet, Porter, Desimone, Birman, & Yoon, 2001; Penz & Bassendowski, 2006). Consequently, large quantities of money, resources, time, and effort are expended to research, deliver, and improve professional development practices (Ball & Cohen, 1999; Borko, 2004). Specifically in the area of teacher professional development, Yoon, Duncan, Lee, Scarloss, & Shapley, K. (2007), found that “teachers who receive substantial professional development–an average of 49 hours in a year–can boost their students’ achievement by approximately 21 percentile points” (p.5). Furthermore, Jaquith, Mindich, Wei, & Darling-Hammond (2010) add that “limited professional development–between 5 and 14 hours in total showed a not statistically significant effect on student learning” (p.9). Findings such as these solidify the value of long-term professional development for educators.
Furthermore, empirical research has demonstrated for over two decades that effective professional learning continues over the long term and is best situated within a community that supports learning (Darling-Hammond, 1997; Garet, et al., 2001; Stoll, Bolam, McMahon, Wallace, & Thomas, 2006; Wenger, 1998). Within a performance or accountability framework, such as that which is found in the field of education, the onus shifts toward workers to verify their competence in an observable way (Barnett, 2000; Usher & Edwards, 1994). The assumption that through continuing learning, professionals will maintain competence and develop expertise is the basis on which much current professional development is predicated.

For the purposes of this study the core features of Contact Hours and Sustained Time addressed the need for the professional development to meet society’s expectations for effective professional learning. To be effective, the intensive ongoing professional development must be longer than 14 hours and continued over a long term. There were thirty contact hours built into the intensive ongoing professional development over a ten-week period. What is not addressed in the core features of contact hours and sustained time are homework that is completed outside of class and the time to drive to the week professional development sessions.

**Effective professional development.** Stein, Smith, & Silver, (1999) point to a significant research base outlining some basic principles for designing professional development that school and district leaders as well as policy makers would be well-advised to consider. First of all, intensive professional development, especially when presented in context with direct applications of knowledge to teachers’ planning and instruction, has a greater chance of influencing teaching practices and, in turn, leading to gains in student learning (Knapp, 2003; Cohen & Hill, 2001; Desimone, et al., 2002; Garet, et al., 2001; McGill-Franzen, et al., 1999; Supovitz, Mayer & Kahle, 2000; Weiss & Pasley, 2006). Secondly, professional development
should focus on student learning and address the teaching of specific curriculum content. A third research-based professional development principle supports the alignment of professional learning with school improvement priorities and goals. Research suggests that professional development tends to be more effective when it is an integral part of a larger school reform effort, rather than when activities are isolated, having little to do with other initiatives or changes underway at the school, district, regional, or state level (Elmore & Burney, 2007; Cohen & Hill, 2001; Garet, et al., 2001; Penuel, Fishman, Yamaguchi & Gallagher, 2007; Supovitz, Mayer & Kahle, 2000). Professional development, which builds strong working relationship among teachers, is the fourth research-based professional learning principle.

**Professional development principle: intensive professional learning.** Intensive professional development, especially when presented in context with direct applications of knowledge to teachers’ planning and instruction, has a greater chance of influencing teaching practices and, in turn, leading to gains in student learning (Knapp, 2003; Cohen & Hill, 2001; Desimone, et al., 2002; Garet, et al., 2001; McGill-Franzen, et al., 1999; Supovitz, Mayer & Kahle, 2000; Weiss & Pasley, 2006). According to results from a national survey, teachers view in-service activities as most effective when they are sustained over time (Garet, et al., 2001). For the purposes of this study, the question was asked, what would the participants find valuable?

To learn what would directly apply to teacher planning and instruction results from standardized testing and a Professional Development Needs Assessment were analyzed. As noted in Chapter III, a Professional Development Needs Assessment was distributed electronically to the teachers of the intermediate unit special education classrooms, the CASD mathematics teachers and the RLASD mathematics teachers who instruct students in grades K-8. The Professional Development Needs Assessment is a close response tool that is differentiated
by teaching assignment. After denoting which grade level they were assigned to teach, the teacher was directed to the portion of the tool corresponding to the mathematical content taught at that grade level. By specific grade level check boxes were provided in the strands of mathematics the Pennsylvania Department of Education expects to be mastered at that grade level. Thirty-five teachers completed the professional development needs assessment to provide direction to the researcher for mathematical content to include in the intensive, ongoing professional development. Teacher responses were evenly distributed across all content areas (See Table 23).

Table 23

<table>
<thead>
<tr>
<th>Requested Area of Professional Development</th>
<th>Counting &amp; Cardinality</th>
<th>Operations &amp; Algebraic Thinking</th>
<th>Numbers &amp; Operations in Base Ten</th>
<th>Measurement &amp; Data</th>
<th>Geometry</th>
</tr>
</thead>
<tbody>
<tr>
<td># of Teachers</td>
<td>12</td>
<td>9</td>
<td>10</td>
<td>10</td>
<td>11</td>
</tr>
</tbody>
</table>

In addition to the results of the Professional Development Needs Assessment, the student results of the Pennsylvania State System of Assessment were examined to provide direction to the researcher for the mathematical content to be included in the intensive, ongoing professional development. The primary purpose of the PSSA is to determine student achievement level of individual students, the PSSA mathematics assessment is a logical and appropriate instrument to measure the mathematics professional development content that would be of value to the study participants and ultimately their students. By comparing the measure of achievement of the participating LEAs with the professional development needs assessment results the content (i.e. Numbers and Operations, Algebraic Concepts, Geometry or Measurement) of potential value to the participants was determined. The mathematical strands, Numbers and Operations and
Measurement were the lowest two reporting categories for CASD and RLASD students in grades three, and five, six, and seven as well as the special education students in the intermediate unit classrooms. For these reasons, the Focus on Content was narrowed down to Numbers and Operations, a mathematical strand of the Pennsylvania Academic Standards as well as area of stated need on the Professional Development Needs Assessment.

Professional development principle: focus on student learning. Professional development that includes the modeling of classroom practices is more likely to be utilized by teachers (Snow-Renner & Lauer, 2005; Carpenter, 1989; Cohen & Hill, 2001; Garet, et al., 2001; Desimone, et al., 2002; Penuel, Fishman, Yamaguchi, & Gallagher, 2007; Saxe, Gearhart & Nasir, 2001; Supovitz, Mayer & Kahle, 2000). Likewise, teachers judge professional development to be of the greatest value when it provides opportunities to do “hands-on” work that builds their knowledge of academic content and how to teach it to their students, as well as when it takes into account the local context of school resources, curriculum maps, and data systems (Garet, et al., 2001).

The second principle of professional development was addressed through the core features of Active Learning and Public Examination of Practice. Each participant was given a kit of manipulatives that included items such a base ten blocks, graphing paper, and Unifix cubes. These math manipulatives were used to make the abstract concrete. In addition to math manipulatives, models and small group discussions were utilized to engage the learners. Videos of teacher demonstrating content area pedagogy were embedded into each of the ten week sessions. Small and whole group discussions of the pedagogies observed served as a Public Examination of Practice.
Professional development principle: integrated into school reform. Research suggests (Elmore & Burney, 2007; Cohen & Hill, 2001; Garet, et al., 2001; Penuel, Fishman, Yamaguchi & Gallagher, 2007; Supovitz, Mayer & Kahle, 2000), that professional development tends to be more effective when it is an integral part of a larger school reform effort, rather than when activities are isolated, having little to do with other initiatives or changes underway at the school, district, regional, or state level. Public schools in Pennsylvania were in a state of transition from the Pennsylvania Academic Standards to the Pennsylvania Core Standards during the period of this study. The mathematical strand of Numbers and Operations exist in both sets of standards. The expectations under the Pennsylvania Core Standards are higher than the expectations of the Pennsylvania Academic Standards. A clear delineation between the two sets of standards is the explicit expectation of the Standards of Mathematical Practice in the Pennsylvania Core Standards. In group discussion and through class assignments, the instructor modeled and expected participants to use the standards of the mathematical practices including: (1) make sense of problems and preserve in solving them; (2) reason abstractly and quantitatively; (3) construct viable arguments and critique the reasoning of others; (4) model with mathematics; (5) use appropriate tools strategically; (6) attend to precision; (7) look for and make use of structure; and (8) look for and express regularity in repeated reasoning. On the end of program questions the participants rated how well the instructor connected the content of the Numbers and Operations course with other professional learning as 2.8 on a four-point scale. However on the open ended response items on both the end of program questionnaire and end of program evaluation the mathematical practices are indirectly referenced in the hands-on, active learning activities participates cited as the most useful aspect of the course. The difference in
Table 24

*Matching Standards of Math Practices to Participants’ Responses*

<table>
<thead>
<tr>
<th>Mathematical Practice</th>
<th>Identify the most useful concept from the workshop that will influence your instruction of mathematics.</th>
</tr>
</thead>
</table>
| 1) Make sense of problems and preserve in solving them. 3) Reason abstractly and quantitatively. | The last concept- fractions, ratios and percentages  
Dividing fractions using a common denominator  
It was extremely helpful to see new ways of understanding multiplication and division other than the standard algorithm.  
Inquiry based learning techniques  
It made me think  
The great tactics for teaching my students some challenging skills!  
Problem solving - the steps, processes, and types of the chapters on it and class gave me a whole new perspective.  
I found the use of manipulatives to make math more concrete to be the most useful.  
The emphasis on conceptualization  
Conceptualization is a missing key |
| 4) Model with mathematics. 5) Use appropriate tools strategically. 6) Attend to precision. 7) Look for and make use of structure. 8) Look for and express regularity in repeated reasoning. | The area models were most useful for multiplication of fractions.  
The use of different models and manipulatives to explain math concepts  
Number theory concepts with visual models  
Teaching Greatest Common Factor and Least Common Factor using Venn Diagrams - love it!  
The use of manipulatives for the four basic operations and the understanding of fractions.  
Hands-on students need to understand the concept to really learn it.  
Move students from concrete thorough understanding (with visuals, manipulatives) to abstract  
Area model for GCF/LCM; using manipulatives to teach math concepts bases (4 and 5 as opposed to base 10) |
| 2) Construct viable arguments and critique the reasoning of others. | Being able to network and socialize with peers  
Facilitate discussion among my students |
close-ended responses and the open ended responses, related to the principle of integrating professional learning with larger school reform, is semantics (See Table 24).

**Professional learning principle: builds strong working relationships.** Professional development, which builds strong working relationship among teachers, is the fourth research-based professional learning principle. Strategically creating time and productive working relationships within academic departments or grade levels, across them or among teachers school-wide, the benefits can include greater consistency in instruction, more willingness to share practices and try new ways of teaching, and more success in solving problems of practice (Hord, 1997; Joyce & Calhoun, 1996; Louis, Marks & Kruse, 1996; McLaughlin & Talber, 2001; Newman & Wehlage, 1997; Successful California Schools, 2007). By sharing pedagogies, discussing problems and solutions teachers foster a better understanding of the goals of student learning and proposed changes in teaching. The core feature of Coherence was measured on the end of program evaluation with the following question: How well did the instructor maintain a professional climate that promoted learning? On a four-point scale the participants rated this aspect of Coherence as 3.9, the highest rated category on the end of program evaluation. On the end of program questions the close-ended question was asked in slightly different language. How well the instructor facilitated discussions among the teachers in the Numbers & Operations course was rated as 3.4 on the four-point scale. Suggestions from the participants reveal why the core feature of Coherence did not receive the highest ranking from all participants (Table 25). What was not measured was whether participants discussed what they learned with other teachers in their school or department or shared what they learned with the administrators.
Table 25

Participants’ References to Coherence

| I liked working in small groups however at times I would of liked to have had more large group discussions when small groups were struggling. |
| I would like to say- allow us to sit where we want but I know I grew from having to sit where assigned. |
| Not all of the participants were pure math teachers. As a result those with a daily focus on only math were more advanced and tended not to be very helpful to those of us that were struggling. It might be helpful to find a way to provide the same course work but with different grouping. |

The historical perspective of professional development. Scientific management and bureaucratic systems dominated beliefs about improving teacher delivery of instruction in the 1800s and 1900s. Systems of bureaucracy such as Cubberly’s standardized chain of command provided the backdrop for increased teacher isolation (DuFour & Eaker, 1998). The continued bureaucracy in education over the course of the twentieth century led a call for and examination of education in the United States and to the publication of A Nation at Risk. The report, A Nation at Risk cited evidence obtained by the National Commission on Excellence in Education which indicated increased mediocrity in U.S. schools, coupled with evidence that American students were not keeping pace with international peers (U.S. Department of Education, 1983).

Title II, Part B, of the Elementary and Secondary Education Act, with a 1999 appropriation of about $335 million, is a source of funding for professional development activities that are wide-ranging and include workshops and conferences, study groups, professional networks and collaboratives, task force work, and peer coaching. Title II, Part B, also known as the Eisenhower Professional Development program, funding is channeled through state educational agencies to school districts, and through state agencies for higher education to
grantees. The American Institutes for Research under contract with the U.S. Department of Education’s Planning and Evaluation Service, conducted multi-year evaluations of the Eisenhower Title IIB Program which examined the relationship between features of professional development and self-reported change in teachers’ knowledge and skill and classroom teaching practices (Garret, et al., 2001). A 1997 longitudinal study with a national sample, which included 93% of districts in the country, surveyed 1,027 teachers and built upon the research premise of Garet et al., (2001). Desimone et al., (2002) concluded that the key features of professional development (i.e. reform type, duration, collective participation, active learning, coherence and content focus), could be hypothesized as effective and were related to increases in teachers’ self-reported knowledge and skills and changes in teacher practice. Furthermore based on the national teacher self-reported data gathered on the prevalence of the six characteristics and teacher perception of the effect on their knowledge, skills, and classroom practices it was found that most district supported professional development activities do not have the six high-quality characteristics (Desimone et al., 2002).

Fulton, Yoon and Lee (2005) acknowledged that the current factory model school is in fact grossly inefficient, inappropriate, and ultimately inequitable, requiring all children to adapt to the mean. “Those who do not learn at the speed of the assembly line lose out and/or drop out: those who could learn more do not. Individualizing instruction for each learner is no longer a dream—it is an educational birthright for all children” (Fulton, 2003, p. 32). In comparison, the factory model of professional development relies heavily on the classic teacher in-service days with experts leading one-shot infusions of new ideas to large groups of teachers on broad topics (i.e. differentiated instruction, diversity, positive behavior management, technology integration) or they might focus on product implementation of corporate-created curricula (Hinchey &
Many educational agency initiatives are fragmented, top-down, and embody, according to Fullan and Hargreaves, “a passive view of the teacher, who is empty, deficient, lacking in skills, needing to be filled up and fixed with new techniques and strategies” (1996, p.17). Desimone, et al., (2002) concur that “schools generally do not have a coherent, coordinated approach to professional development and instruction, at least not an approach that is effective in building consistency among their teachers” (Desimone, et al., 2002, p. 105). Furthermore participation in professional development is largely an individual teacher’s decision and teachers often choose professional learning from a number of options available provided by dissimilar providers (Skyes, 1996). With a highly disparate set of professional development providers, much of the variation in professional development and teaching practice is between individual teachers within schools, rather than between schools (Desimone, et al., 2002).

Around the same time Cubberley promoted a bureaucratic system, Dewey celebrated the power of new ideas, insightful critique and continuous inquiry that challenged the ideological and institutional “regimes of truth.” Dewey’s call for “continuous discovery of truth” mirrors Fullan’s (1991) call for the redesign of the educational workplace to include daily activities where educators manipulate information to encourage innovations and improvement of their craft. Newman & Wehlage (1995) identified the practice of organizing information for interpretation and consideration of alternatives as a standard of authentic pedagogical practice. In their seminal study, of student learning in more than 24 significantly restructured schools, sampling over 10,000 students from grades eight through twelve, Newman & Wehlage (1995) concluded that education reform measures often place too much emphasis on school restructuring practices which do not directly address the issue of student learning. Additionally, through the use of content, process, and written communication, learners used the information
provided to create and better understand concepts practiced. Senge (1990) posits that organizations desiring positive and effective change must focus on collaborative and continuous learning. Collaborative learning promotes the growth of the organization rather than the individual educator. The professional learning community is a collegial group of administrators and teachers who are united in the commitment to student learning, share a vision, work and learn collaboratively, visit and review each other’s classrooms, and participate in decision making (Black, 2007; Hord, 1997). Eacker, DuFour, and Burnette (2002) suggested that communities of learners build productive relationships necessary for collaboration, partnerships, reflection and implementations of school improvement programs.

The historical perspective of professional development strongly connected to the design of this research study. The Numbers and Operations intensive, ongoing professional development program was the first course in a series of six courses aligned to the mathematical strands of the Pennsylvania Core Standards. The American Institutes for Research examination of the relationship between features of professional development and self-reported change in teachers’ knowledge and skill and classroom teaching practices (Garret, et al., 2001, Yoon) created the framework for effective professional development. Within the framework sponsorship, the structural features, the core features and the outcome of enhanced knowledge and skill were building blocks of the research design. Extending upon the seminal research of Garret, et al., (2001) to weave in the findings of Fullan and Hargreaves (1996), that a teacher is not empty, deficient, or lacking in skills, and Desimone, et al., (2002) that schools generally do not have a coherent, coordinated approach to a professional development plan to offer a multi-year professional development plan for the purpose of developing teacher content knowledge and teacher pedagogical knowledge with a professional learning community. The series of six
intensive, ongoing professional development courses aligned to the mathematical strands of Numbers and Operations, Geometry, Algebraic Concepts, Measurement, Data Analysis and Probability. The Numbers and Operations intensive, ongoing professional development ten-week course, the first in the series, was the subject of this research study.

The research on ongoing professional development. Identifying cultural barriers such as established norms, attitudes, beliefs, behaviors, values, ceremonies, traditions, and myths that are deeply ingrained in the very core of the organization that schools need to overcome to support good professional development is the first step in changing the school’s culture. Fullan (2002), found a starting point of cultural change to be in the belief in the importance of “teachers as learners,” and the understanding that improving practice by acquiring new knowledge and skills is a professional obligation. According to Chappuis, Chappuis & Stiggins (2009) teachers are accustomed to staff development or professional learning where the presenter has all the responsibility for action and the participants’ responsibility is limited to being physically present. To progress toward a collegial professional development model, the understanding that professional development can be a team experience that involves all participants, focuses learning on a specific topic and strengthens classroom practice is needed. (Chappuis et. al., 2009) For example, learning is brought to the team through an expert, by reading books or articles, or viewing footage of classroom practice. This information is transferred to the teachers’ context by preparing lessons, materials, and activities to use with students. Participants then observe, reflect on the results, as well as discuss, problem solve, and create. As teachers share what they have learned, what they tried, observed, and what happened with students in an environment that sets the expectations for the team to come prepared, remain focused on helping students,
participate, and stay on topic they begin to grow into a collegial community of learners (Chappuis, et al., 2009).

The intensive, ongoing professional development in this study is connected to the research base on ongoing professional development. The core features of Focus on Content, Active Learning, Coherence, & Public Examination of practice mirrors Chappuis et.al, descriptions of a team lead through an expert, reading books, viewing footage of classroom practice. The facilitator of the intensive, ongoing professional development is considered an expert, as he is a national level professional development provider as well as a professor in the education department of an institute of higher education. The participants read and discussed a text selected by the facilitator and viewed video footage of teachers implementing mathematical pedagogies in classroom settings. Participants were asked to participate in small group discussions, problem solve and acknowledge these expectations in the responses on the end of program evaluation (Table 26).

Table 26

**Participant Reflections on Core Features of Professional Development**

<table>
<thead>
<tr>
<th>Reflection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem solving - the steps, processes, and types of the chapters on it and class gave me a whole new perspective.</td>
</tr>
<tr>
<td>I found the use of manipulatives to make math more concrete to be the most useful.</td>
</tr>
<tr>
<td>Videos of mathematical instruction in the content area of Numbers and Operations as well as discussion of instructional strategies.</td>
</tr>
<tr>
<td>The videos of others completing the tasks were useful as well.</td>
</tr>
<tr>
<td>Hands-on students need to understand the concept to really learn it.</td>
</tr>
</tbody>
</table>

The research on effective professional developments strongly connects of the study design. Effective professional development continues over the long term, is related to
professional’s work and is situated in a community of learns. Professional learning that focuses on student learning, addresses the teaching of specific curriculum content, is “hands-on,” aligned to school reform efforts and builds productive working relationships is valued by teachers. Without a prescription, model, program or innovation such as the provided through the seminal research on effective professional development with the Title IIB Math and Science Partnership grant program, this research study would align more so to the traditional in-service professional learning that follows the failed bureaucratic systemic thinking. The framework of effective professional development and the direct link of sponsorship, structural features, core features and outcomes and their basis in literature were the building block of the research design and study.

**Limitations of the Study**

The following limitations should be considered when interpreting the results of the study:

1. The study collected data from one intermediate unit in rural, south central Pennsylvania. Findings may not be generalized to other professional development providers.

2. The study does not include an analysis of a teacher control group that did not participate in the intensive, ongoing professional development program; therefore comparing participants and nonparticipants is not present.

3. The small sample of participants may not be representative of all K-8 mathematics teacher perceptions of an intensive, ongoing professional development programs.

4. It may be viewed as a limitation that the researcher is also a professional development specialist at the intermediate unit participating in the study.
5. The pre- and post-test results were directly impacted by participant diligence to answer every question and explain their mathematical thinking.

6. The generalized questions end of program evaluation and resulting tri-plot provided conflicting results to the specifically designed end of program questionnaire.

The limitations regarding the role of the researcher and results of the data warrant additional elaboration. While the intermediate unit employs the researcher, a national professional development provider carried out the facilitation of the intensive, ongoing professional development. In consultation with the professional development provider, it was decided to utilize the Diagnostic Assessment Teachers of Mathematics pre- and post test, as well as the end of program evaluation and end of program questionnaire. The end of program questionnaire was a tool used by the professional development provider in previously offered professional development offerings and gathered information about participant perception of the facilitation and type of learning. The end of program questionnaire was added to ensure data was collected specifically collected on the perceived presence of the core features of effective professional development.

The data gathered was limited by participants’ observed perseverance and by the wording of the assessment tools. Participant perseverance was needed to answer all 20 multiple-choice questions and provide explanations of their mathematical thinking for each item. On the pre-test participants dedicated 60-75 minutes to finish the assessment. However, participants completed the post-test assessment in 30-45 minutes. A review of the post-test assessments identified that not all participants completed the full instrument. Only three participants answered every question completely with both a mathematical calculation and an explanation for each of the 20 questions. Additionally, on the last day of the professional development program participants
were also asked to complete an end of program evaluation. Turning in the final assignment, completing the post-test assessment and completing the end of program evaluation were the only agenda items for the final session of the intensive, ongoing professional development. Participants’ desire to finish the final tasks of the professional development, the quick pace in which participants completed the post-test, and incomplete answers on the post-test impacted participants’ perseverance, the post-test scores and results of this study.

Beyond perseverance, the data gathered was also limited by the wording of the questions on the end of program evaluation. The end of program evaluation incorporated terms such as “learning,” “cognition” and “teaching” for participants to rate without explaining the definition of each term. The end of program questionnaire used specific vocabulary and phrases such as “hands-on,” “discussion” and “connect learning to daily school life.” The resulting data from the end of program questionnaire and end of program survey produced conflicting results and a limitation to the study. Classification of the open-ended responses by the specific names of the core features of effective professional development created clarity for the researcher. Through the classification process, the participants’ open-ended responses clarified their close-ended responses. Additionally the participants are educators and may have been able to translate or equate the varied terminology making the limitation less significant. The participants demonstrated this vocabulary skill when interpreting the directions on the post-test that include phrasing such as “explain your thinking,” “justify your response,” “what is the student’s misconception,” and “describe an instructional strategy” to prompt a narrative response.

Nonetheless, given the limitations listed above, the data gathered from the assessment proved to be valuable. In planning effective professional development the higher education and regional educational association partners specifically addressed the structural features and core
features of effective professional development. As a result of the intentional planning the outcomes of the planned professional development demonstrated a positive impact on teacher content knowledge and teacher pedagogical knowledge. The impact of the participants’ perceived presence of the core features of effective professional were made clear by categorizing participants open-ended responses. The impact of the participants’ perceived presence of the core feature may have been even greater if the aforementioned features were specifically illuminated for the benefit of the participants during the intensive, ongoing professional development. In other words, despite the previously listed limitations the outcomes of the study were achieved yet had the potential to be of greater impact.

Relationship to the Research

The enhanced knowledge and skill of the K-8 teachers in this study concurred with earlier research suggesting that effective professional development which incorporates the core features of Active Learning, Focus on Content Knowledge, Coherence, and Public Examination of Practice in an intensive, ongoing program impacts teacher content and pedagogical knowledge (Stein, Smith & Silver, 1999). Data reported from this study also illustrate that teachers judge professional development to be of the greatest value, when it provides opportunities to do “hands-on” work that builds their knowledge of academic content, shows how to teach it to their students and takes into account the local context of school resources, curriculum maps, and data systems (Garet, et. al., 2001). These data support the findings reported in the review of the literature which suggested effective professional development can deepen teachers’ knowledge, build their skills and improve their instruction (Bryk, Camburn, & Louis, 1999; Calkins, Guenther, Belfoire, & Lash, 2007; Goddard, Goddard, & Tschannen-Moran, 2007; Lois & Marks, 1998; Supovitz & Christman, 2003).
**Content knowledge.** Following participation in an intensive, ongoing professional development program, K-8 teachers increased significantly in content knowledge which suggests a correlation to Shulman’s (1986) notion that content knowledge needed for teaching also involves knowing “why something is so, not just that it ‘is’.” Furthermore, mathematics understanding is described as the “the dynamic, constructed, and reconstructed process of sense making by the learner” and “learning to represent or communicate mathematical ideas or interpret mathematical representations through the use of language, diagrams, pictures, manipulatives, and other tools” (Heaton, 200, p.4). Teachers value professional development when it provides “hands-on” opportunities to build teacher content knowledge of academic content and how to teach their students. Building productive working relationships among colleagues teaching the same content or grade-level can improve consistency of instruction, sharing of practices, and collaborative problem solving. The increase in mathematical content knowledge suggests that the K-8 teachers displayed Knowledge Level II: Conceptual Understanding and Knowledge Level III: Reasoning/Problem Solving Strategies as a result of participating in the intensive, ongoing professional development program that was framed around, Active Learning, Focus on Content Knowledge and Public Examination of Practice- the core features of effective professional development.

**Pedagogical content knowledge.** This study suggests an increase in Pedagogical Content Knowledge resulting from participation in an intensive, ongoing professional development program. According to Wilbrne & Long (2010), teachers teach what they are most comfortable. Shuman (1986) further explains pedagogical content knowledge as the transformation of subject matter knowledge in the context of facilitating student understanding and anticipating particular preconceptions or learning difficulties of their students. This study supports research that
suggests an increase in pedagogical content knowledge occurs as a result of Active Learning, Public Examination of Practice, and a Focus on Content Knowledge, or the core features of effective professional development. Data from this study suggest the use of math manipulatives, models, hands-on or visual models, (Active Learning) small group discussions and lesson study (Public Examination of Practice) positively impacted the increase in pedagogical content knowledge.

**Core features of effective professional development.** This study supports merging the core features of effective professional development, into a framework, to enhance the knowledge and skill of teachers. Effective professional development core features include the following: 1) Professional development that focuses on academic subject matter such as math and science 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, Porter, Desimone, Birman, & Yoon, 2001); 2) Professional development that is connected to other learning and includes groups of teachers from the same school improves teacher content knowledge, and pedagogy (Garet, Porter, Desimone, Birman, & Yoon, 2001); 3) Additionally sustained and intensive professional development has more impact than shorter professional development (Garet, Porter, Desimone, Birman, & Yoon, 2001); and 4) Tyminski, Ledford, & Hembree (2010) indicate that when educator change is one goal of professional development, devices such as post program surveys, interviews, or data from participants’ own teaching, selected mathematical tasks and assessment, or classroom observations are utilized to open participants’ practices to discussion and to examination of those practices in a more public way.
Data indicate that K-8 teacher perception of the presence of the core features of effective professional development, in the intensive, ongoing professional development program were inconsistent. In close-ended questions, K-8 teachers indicated the core features were present in some degree. In open-ended questions, K-8 teachers indicated the feature of Active Learning was present to a high degree and a Focus on Content was not present to the same degree. Further categorization of the open-ended responses revealed K-8 teachers did not connect Active Learning within the program to a Focus on Content. Explicit instruction of the core features of effective professional development may be needed to improve participant identification of the core features.

**Implications for Practice**

Offering a ten-week intensive, ongoing professional development program for K-8 mathematics teachers, in partnership with an IHE and with three data collection sources may not be a cost effective, realistic or manageable option for an LEA. The cost of reimbursement of college credits, and resulting movement on the pay scale are expenses that could prohibit offering a ten-week intensive, ongoing professional development program. Additionally recruiting participants to dedicate thirty hours of time beyond the contracted school may not be realistic for an LEA. In-depth analysis of multiple data sources to determine if the professional development program was indeed effective may not be manageable for an LEA. This begs the question of what can be learned from the study of an intensive, ongoing program that can be translated to current professional development practices?

Apart from these possible concerns, the structural features and core features from the Framework for Effective Professional Development can provide guidance for professional development providers. Regardless if the professional development is planned to occur in the
local education setting on traditional teacher in-service days or off site at a conference facility, the collective participation, sustained time and contact hours can be built into the professional development plan. Differentiating the professional development by content and grade level taught allows for collective participation. Intentionally each session of the intensive, ongoing professional development should include a focus on content, active learning, coherence, and public examination of practice in order to achieve enhanced knowledge and skill.

Examples of how the core features embedded into mathematics professional development were included in this research project. An example from an English Language Arts lens follows. Text Dependent Analysis a type of standardized test item on the PA Core Aligned Pennsylvania State System of Assessment for the 2014-2015 school year. To create an intensive, ongoing professional development program around Text Dependent Analysis, a series of three full day workshops were created. The first workshop focused on the changes the PSSA, including Text Dependent Analysis. To delve deeper into Text Dependent Analysis, the second workshop focused on the instructional shift of Close Reading and the final workshop focused on the instructional shift of Writing from Sources. A total of fifteen contact hours over three days set the stage for the collective participation of teachers of English Language Arts or literacy in the content area. In each session participants were actively engaged in reading research from experts in the field, small group discussion, application of skills such as annotation, turn and talk, action planning, calibrating student writing, and collaborative note taking. Coherence was built through the connection to the reform movements of the Common Core State Standards, the PA Core Standards, and expectations for the PA Core Aligned PSSA. Small group and whole group discussion promoted Public Examination of Practice. The exit survey also took Public
Examination of Practice one step further as participate named their next steps of implementation and the results were posted (and projected) in a google spreadsheet for all to view.

The outcomes of enhanced knowledge and skill for the intensive, ongoing professional development were not measured in a pre- and post-test format. However, attendance and revenue generation of the Text Dependent Analysis series could be considered measures of the desired outcome. It should be noted that the first workshop was provided as a complementary service to the school districts. A participation fee of $125 per person, per session was charged for the workshops on Close Reading and Writing from Sources. Attendance at any of the three workshops was by choice and participants did not have to attend all the workshops in the series. The measureable outcomes of offering professional development based on the framework of effective professional development included the following: 1) Three hundred thirty-eight participants attended the workshops; and, 2) The fee-based workshops generated over $18,000 in revenue. In an era where schools remain under tight economic constraints and enacted a travel moratorium for teacher professional development such outcomes are unprecedented. These outcomes were directly related to the inclusion of the structural features and core features of effective professional development into the intensive, ongoing professional development program.

**Recommendations for Further Research**

This study provided insight into the impact of intensive, ongoing professional development on teacher content and pedagogical knowledge, as well as the perceived presence of the core features of effective professional development. Recognizing the continuing need to develop teacher content knowledge and teacher pedagogical knowledge, as well as to provide
effective professional development, the following recommendations for further research are suggested:

1. Determine the relationship between the degree of improvement in content and pedagogical knowledge to the perceived presence of the core features of effective professional development.

2. Compare the instructor’s perception of the presence of the core features of effective professional development to the participants’ perception.

3. Conduct further research to determine how participation in an intensive, ongoing professional development program impacts student achievement.

4. Conduct further research to determine how the explicit connection of the core features of professional development to the course content impacts Content and Pedagogical knowledge post-test scores.

5. Conduct further research to determine if the incorporation of lesson study using participant-created videos, increases the perception of the presence of the core feature Focus on Content Knowledge

Conclusion

This study examined the impact of an intensive, ongoing professional development program on teacher content and pedagogical knowledge, as well as the perceived presence of the core features of effective professional development. Three hours per week of intensive professional development focused on the mathematical strand of Numbers and Operation which incorporated the core features of effective professional development through discussion, lesson study, the use of math manipulatives and problem solving strategies was conducted over a ten-week period. Data consisted of open-ended and closed-ended questions from an end of program
evaluation, an end of program questionnaire as well as pre- and post-tests gathered from seventeen K-8 teachers. Based on the participants’ response to the three research questions in the study, participants positively increased in content knowledge and pedagogical knowledge, as well as perceived the core features of effective professional development, as present in the program.

Findings from this study contribute to the existing literature on effective professional development’s impact on teacher content and pedagogical knowledge. The investigation of a teacher’s perceptions of the presence of the core features of effective professional development may provide useful insight into the creation and continuation of effective professional development practices. These findings may influence professional development providers considering implementing effective professional development practices.

Building intensive, ongoing professional development upon the framework of effective professional development produces a design that incorporates sponsorship, the structural features, the core features and outcomes of effective professional development. Ultimately the enhanced content knowledge and pedagogical content knowledge leads to changes in teaching practices, changes in the local educational agency and changes in student achievement.

Professional development for educators that is focused on student learning and addresses the teaching of specific curriculum content is more likely to be utilized by teachers. Teachers value professional development when it provides “hands-on” opportunities to build teacher content knowledge of academic content and how to teach their students. Professional development that is aligned to school improvement goals, school resources, curriculum maps and data systems is more effective than learning that is disconnected to school reform efforts or changes in progress at the school, district, or state level. Building productive working relationships among colleagues
teaching the same content or grade-level can improve consistency of instruction, sharing of practices, and collaborative problem solving. The billions of dollars spent on professional learning for educators, when building upon the framework of effective professional development aligns with Taylor’s (1915) principles of scientific management, Dewey’s (1929) “regimes of truth” and Fullan’s (1991) call for “…educational workplace to include daily activities where educators manipulated information to encourage innovations and improvement of their craft” and can significantly impact teacher content knowledge and teacher pedagogical knowledge.
Appendix A

Professional Development Needs Assessment

Thank you for taking this survey! We will use your responses to create professional development opportunities in Science and Math. Please read each question carefully.

* Required

Teaching Assignment *

Please choose the level of your teaching assignment. If you have multiple teaching assignments, please choose the most appropriate grade level.

- [ ] K
- [ ] 1
- [ ] 2
- [ ] 3
- [ ] 4
- [ ] 5
- [ ] 6
- [ ] 7
- [ ] 8

Does your teaching assignment include working with students who utilize accommodations in any of the following areas? *

Please choose all descriptors that apply.

- [ ] English Language Learners
- [ ] IEP for Learning Needs
- [ ] Vision Impaired/Blind
Deaf/Hard of Hearing
Alternative Education

What is your comfort level in teaching 21st century math and science content to your students? *

Please choose the responses that apply.

☐ I would like to increase my knowledge in 21st century math/science.
☐ I would like to learn additional strategies to meet the diverse learning needs in my classroom.
☐ I have a "toolbox" of techniques I could share with others.
☐ I feel prepared to instruct in 21st century math &/or science content.

Which CCSS mathematical practices are you currently using in your classroom?

Please choose the responses that apply.

☐ Make sense of problems and persevere in solving them.
☐ Reason abstractly and quantitatively.
☐ Construct viable arguments and critique the reasoning of others.
☐ Model with mathematics.
☐ Use appropriate tools strategically.
☐ Attend to precision.
☐ Look for and make use of structure.
☐ Look for and express regularity in repeated reasoning.

Which Next Generation Science practices are you currently using in your classroom?

Please choose the responses that apply.

☐ Asking questions (for science) and defining problems (for engineering)
☐ Developing and using models
☐ Planning and carrying out investigations
☐ Analyzing and interpreting data
☐ Using mathematics and computational thinking
☐ Constructing explanations (for science) and designing solutions (for engineering)
☐ Engaging in argument from evidence
☐ Obtaining, evaluating, and communicating information
What format would you prefer for professional development

Please choose all that apply

☐ Summer, week long, session

☐ Summer, week long, for-credit, college course

☐ Summer, week long, for-credit, college course with course reimbursement *pending grant award

☐ 20 minutes on-line, ongoing support sessions (PLC)

☐ In-service days built into school calendar.

☐ On my own time

☐ Saturday sessions

Continue »
End of program evaluation

How much impact did the workshop have on your professional growth?
1 2 3 4

How well did the instructor maintain a professional climate that promoted learning?
1 2 3 4

How well did the instructor facilitate your understanding of the material in this workshop?
1 2 3 4

How likely are you to recommend future workshops facilitated by this instructor to a colleague?
1 2 3 4

Identify the most useful concept from the workshop that will influence your instruction of mathematics.
Offer one suggestion for the instructor to improve the facilitation of this workshop.

What is your certification?

What do you teach?

Month/day of birth?

Submit

Never submit passwords through Google Forms.
Appendix C

Diagnostic Teachers Assessment in Mathematics & Science

Whole Number & Computation Assessment - Version 3.3
Diagnostic Teacher Assessments in Mathematics and Science
Elementary Mathematics

Please provide the following information about yourself:

Years of teaching experience:
(0 if pre-service teacher)

Number of college math courses:

The year you received your most recent teaching degree or rank:

Gender: M ☐ F ☐

Grade level(s) currently teaching:
(Check all that apply)

Teaching certificate grade levels:
(Check all that apply)

Teaching certificate content area(s):
(Check all that apply)

Last 4 digits of Soc. Sec. #: ☐ ☐ ☐ ☐

Directions for completing items:
Please record date and starting and finishing times in the spaces in the upper right-hand corner of this page. It is very important to fill out the demographic information above, especially the last 4 digits of your SSN, as test results will be reported using that as your ID.
Please answer all questions as completely as possible. Show all work in responding to items and briefly explain your thinking on all items. Let the test facilitator know when you are finished. Thank you very much for your time.

<table>
<thead>
<tr>
<th>#</th>
<th>Item</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Which of the following is expanded notation for the number 439,0057?</td>
<td>☐ a. 439,000 + 5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>☐ b. 439 × 1,000 + 5 × 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>☐ c. 100,000 + 8,100,000 + 8,100,000 + 0 + 0 + 10 + 5 + 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>☐ d. 4 × 100,000 + 3 × 10,000 + 9 × 1,000 + 5</td>
</tr>
<tr>
<td>2</td>
<td>Which of the following numbers, when rounded to the nearest thousand, becomes 43,000?</td>
<td>☐ a. 43,498</td>
</tr>
<tr>
<td></td>
<td></td>
<td>☐ b. 44,187</td>
</tr>
<tr>
<td></td>
<td></td>
<td>☐ c. 43,501</td>
</tr>
<tr>
<td></td>
<td></td>
<td>☐ d. 43,587</td>
</tr>
<tr>
<td>3</td>
<td>Using whole numbers, for which two operations does the commutative property hold?</td>
<td>☐ a. addition and division</td>
</tr>
<tr>
<td></td>
<td></td>
<td>☐ b. division and subtraction</td>
</tr>
<tr>
<td></td>
<td></td>
<td>☐ c. multiplication and division</td>
</tr>
<tr>
<td></td>
<td></td>
<td>☐ d. addition and multiplication</td>
</tr>
<tr>
<td>4</td>
<td>Solve: “36 ÷ (3 + 9) = [ ]”</td>
<td>☐ a. 3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>☐ b. -3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>☐ c. -6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>☐ d. 6</td>
</tr>
</tbody>
</table>
### Whole Number & Computation Assessment – Version 3.3

<table>
<thead>
<tr>
<th>5</th>
<th>Which one of the following statements is true about all composite numbers?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>a. They are odd numbers</td>
</tr>
<tr>
<td></td>
<td>b. They are even numbers</td>
</tr>
<tr>
<td></td>
<td>c. They have exactly 2 factors</td>
</tr>
<tr>
<td></td>
<td>d. They have at least 2 factors</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>6</th>
<th>Which means the same as 3 ten thousands, 400 tens, and 20 ones?</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. 34,020 b. 70,020 c. 30,420 d. 30,600</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>7</th>
<th>What numbers do A, B, and C probably represent on the number line below?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>![Number Line Diagram]</td>
</tr>
<tr>
<td></td>
<td>a. A = 105, B = 375, C = 655</td>
</tr>
<tr>
<td></td>
<td>b. A = 40, B = 600, C = 710</td>
</tr>
<tr>
<td></td>
<td>c. A = 350, B = 100, C = 650</td>
</tr>
<tr>
<td></td>
<td>d. A = 100, B = 360, C = 400</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>8</th>
<th>Which of the following shows the meaning of $3 \times 4$?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>![Number Representation]</td>
</tr>
<tr>
<td></td>
<td>a. 0000 0000 0000</td>
</tr>
<tr>
<td></td>
<td>b. OOO × OOOO</td>
</tr>
<tr>
<td></td>
<td>c. 0000 0000 0000</td>
</tr>
<tr>
<td></td>
<td>d. 4  ≤3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>9</th>
<th>If a number N has exactly two factors, then N can only be then</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>a. an odd number</td>
</tr>
<tr>
<td></td>
<td>b. a prime number</td>
</tr>
<tr>
<td></td>
<td>c. an even number</td>
</tr>
<tr>
<td></td>
<td>d. a square number</td>
</tr>
</tbody>
</table>
10 If a number greater than 1 is written as a product of its prime factors, which of the following statements is always true?
   a. The number of prime factors of the number is odd
   b. The number of prime factors of the number is even
   c. Each of the prime factors is a divisor of the number
   d. Each of the prime factors is a multiple of the number

11 Francis James, a math teacher, teaches in a special school. The school board pays Francis $1 dollar for each second of teaching. Francis teaches (with no breaks) from 8 am until 4 pm each day, Monday through Friday. Francis starts teaching on the Wednesday after Labor Day. This special school observes no holidays.
   a. Will Francis earn the one-millionth dollar in the morning or afternoon?
   b. Explain your reasoning.

12 Each of the letters in the following addition problem stands for a unique number 0-9. Find the value of each letter and justify your answers.

   H E R E
   + S H E
   -------
   C O M E S

13 I started thinking about the number of sandwiches I could make with individual ingredients. A loaf of bread contains eighteen slices. Each 16-ounce jar of peanut butter will make 12 sandwiches, and each 48-ounce jar of jelly will make 48 sandwiches.
   If I were to start with full loaves of bread and new jars of peanut butter and jelly, how many PB&J sandwiches would I have to make before emptying a bread bag, a jar of jelly, and a jar of peanut butter at the same time?
<table>
<thead>
<tr>
<th></th>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>When three numbers are multiplied their product is -525. When they are added their sum is -3. What are the three numbers?</td>
</tr>
<tr>
<td>15</td>
<td>Justify that the sum of an even number and an even number is an even number.</td>
</tr>
<tr>
<td>16</td>
<td>A student uses the counting strategy ‘counting by three’s to solve 3 + ____ = 12 She explains, “I start at 3 and count by three’s to 12. That’s 3, 6, 9, 12.” (Each time she says a number she raises another finger.) “That’s 4 three’s, so the answer is 12.”</td>
</tr>
<tr>
<td></td>
<td>a. How would you help the student understand her misconception?</td>
</tr>
<tr>
<td></td>
<td>b. How would you help the student understand the correct procedure? Use a drawing or diagram in your explanation.</td>
</tr>
</tbody>
</table>
### Whole Number & Computation Assessment – Version 3.3

#### 17
One student estimates $23\overline{3546}$ by first rounding 23 to 20 and 3546 to 3600.

Explain how you would help the student understand two other methods of estimation.

#### 18
A student during your mathematics lesson used the following steps to solve the subtraction problem: $245 - 158 = \underline{\phantom{000}0}$. Mathematically speaking, why did her method work? Explain.

\[
\begin{array}{c}
245 \\
\downarrow \\
-158 \\
\hline \\
\end{array}
\rightarrow
\begin{array}{c}
245 \\
\downarrow \\
-158 \\
\hline \\
-87
\end{array}
\rightarrow
\begin{array}{c}
245 \\
\downarrow \\
-158 \\
\hline \\
267
\end{array}
\rightarrow
\begin{array}{c}
245 \\
\downarrow \\
-158 \\
\hline \\
87
\end{array}
\]
19. Consider the expression $3 - 6$. Explain how you would help students understand this expression by using two real-world applications of negative integers.

---

20. A student is looking for **all** of the factors of 40. She says to you, “My mom said that after I try 1, 2, 3, 4, 5 and 6, I don’t need to test any numbers larger than 6.” Is her mom correct? Explain why or why not.
Whole Number & Computation Assessment—Version 5.3
Diagnostic Teacher Assessments in Mathematics and Science
Elementary Mathematics

Please provide the following information about yourself:

- Gender: M ☐ F ☐
- Last 4 digits of Soc. Sec. #: ________
- Years of teaching experience: (0 if preservice teacher)
  - 6-8 ☐
  - 9-12 ☐
  - 13-15 ☐
  - 16-12 ☐

- Number of college math courses: ☐
- Grade level(s) currently teaching:
  - K ☐
  - 1 ☐
  - 2 ☐
  - 3 ☐
  - 4 ☐
  - 5 ☐

- Teaching certificate grade levels:
  - Elem. ☐
  - M.S. ☐
  - H.S. ☐
  - Spec. Ed. ☐
  - Admin. ☐
  - Other ☐

- The year you received your most recent teaching degree or rank: __________
- Teaching certificate content area(s):
  - (Check all that apply)

Directions for completing items:
Please record date and starting finishing times in the spaces in the upper right-hand corner of this page. It is very important to fill out the demographic information above, especially the last 4 digits of your SSN, as test results will be reported using that as your ID.

Please answer all questions as completely as possible. Show all work in responding to items and briefly explain your thinking on all items.

Let the test facilitator know when you are finished. Thank you very much for your time.

#   Item                                                                 Answer

1. Which of the following is expanded notation for the number 520,340?
   a. $5 \times 100,000 + 2 \times 10,000 + 3 \times 1,000 + 4 \times 10 + 0 \times 1$
   b. $520,000 + 340$
   c. $520 \times 1,000 + 3 \times 100 + 4 \times 10$
   d. $5 \times 100,000 + 2 \times 10,000 + 3 \times 100 + 4 \times 10$

2. Which of the following numbers, when rounded to the nearest thousand, becomes 22,000?
   a. 23,234       b. 22,876       c. 22,456       d. 23,123

3. Using whole numbers, for which two operations does the commutative property hold?
   a. addition and subtraction
   b. multiplication and division
   c. addition and multiplication
   d. subtraction and division

4. Solve: $12 - (9 - 3) = [ ]$
   a. −6         b. −24         c. −12         d. 0
### Whole Number & Computation Assessment – Version 5.3

<table>
<thead>
<tr>
<th></th>
<th>Question</th>
<th>Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Which one of the following statements is true about all multiples of 3?</td>
<td>a. They are odd numbers</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b. They are divisible by 3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>c. They are factors of 3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>d. They are composite numbers</td>
</tr>
<tr>
<td>6</td>
<td>Which means the same as 3 thousands, 14 hundreds, 7 tens and 16 ones?</td>
<td>a. 314,716</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b. 4,476</td>
</tr>
<tr>
<td></td>
<td></td>
<td>c. 17,716</td>
</tr>
<tr>
<td></td>
<td></td>
<td>d. 4,486</td>
</tr>
<tr>
<td>7</td>
<td>What numbers do A, B, and C probably represent on the number line below?</td>
<td>a. A = 160, B = 375, C = 640</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b. A = 160, B = 520, C = 600</td>
</tr>
<tr>
<td></td>
<td></td>
<td>c. A = 370, B = 400, C = 600</td>
</tr>
<tr>
<td></td>
<td></td>
<td>d. A = 315, B = 560, C = 590</td>
</tr>
<tr>
<td>8</td>
<td>Which of the following shows the meaning of 2 × 5?</td>
<td>a. [Diagram]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b. [Diagram]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>c. [Diagram]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>d. [Diagram]</td>
</tr>
<tr>
<td>9</td>
<td>If a number N has exactly three factors, then N can only be</td>
<td>a. an odd number</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b. a perfect number</td>
</tr>
<tr>
<td></td>
<td></td>
<td>c. a square number</td>
</tr>
<tr>
<td></td>
<td></td>
<td>d. a multiple of 3</td>
</tr>
</tbody>
</table>

---

Whole Number & Computation Assessment Prototype
© University of Louisville Center for Research in Mathematics and Science Teacher Development

Page 2

Version 5.3
10. If a positive non-prime number is written as a product of its prime factors, which of the following statements is always true?
   a. The number of prime factors of a number is never 3.
   b. The number of prime factors is never 1.
   c. The number of prime factors is even.
   d. The number of prime factors is odd.

11. Francis James, a math teacher, teaches in a special school. The school board pays Francis 1 dollar for each minute of teaching. Francis teaches for 8 hours each day, Monday through Friday. Francis teaches 180 days each year.
   a. When will Francis earn the one-millionth dollar? Give your answer to the nearest day, such as 5 years, 12 weeks, and 3 days. (Consider a week to be 5 days of teaching.)
   b. Explain your reasoning.

12. Each of the letters in the following addition problem stands for a unique number 0-9. Find the value of each letter and justify your answers.

\[
\begin{array}{c}
D A N \\
+ N A N \\
\hline
N O R A \\
\end{array}
\]
<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>13</strong></td>
<td>I started thinking about the number of sandwiches I could make with individual ingredients. A loaf of bread contains eighteen slices, although I always feed the two end slices to the birds. Each 16-ounce jar of peanut butter will make 12 sandwiches, and each 48-ounce jar of jelly will make 60 sandwiches. If I were to start with full loaves of bread and new jars of peanut butter and jelly, how many PB&amp;J sandwiches would I have to make before emptying a bread bag, a jar of jelly, and a jar of peanut butter at the same time?</td>
</tr>
<tr>
<td><strong>14</strong></td>
<td>When three numbers are multiplied their product is -390. When they are added their sum is -2. What are the three numbers?</td>
</tr>
<tr>
<td><strong>15</strong></td>
<td>Justify that the sum of an odd number and an odd number is an even number.</td>
</tr>
<tr>
<td></td>
<td>Whole Number &amp; Computation Assessment– Version 5.3</td>
</tr>
<tr>
<td>---</td>
<td>--------------------------------------------------</td>
</tr>
</tbody>
</table>
| 16 | A student uses the counting strategy ‘counting down’ to solve 15 – ____ = 10. She explains, “I start at 15 and count down to 10. That’s 15, 14, 13, 12, 11, 10.” (Each time she says a number she raises another finger.) “That’s 6 fingers, so the answer is 6.”  
   a. How would you help the student understand her misconception?  
   b. How would you help the student understand the correct procedure? Use a drawing or diagram in your explanation. |
| 17 | One student estimates $28 \div 4567$ by first rounding 28 to 30 and 4567 to 4500.  
   Explain how you would help the student understand two other methods of estimation. |
18. A student during your mathematics lesson used the following steps to solve the subtraction problem: 264 - 186 = [ ]. Mathematically speaking, why did her method work? Explain.

\[
\begin{array}{cccc}
264 & 264 & 2 \text{ } 8 & 278 \\
\rightarrow & 199 & \rightarrow & 200 \\
-186 & -186 & \rightarrow & 200 \\
\rightarrow & \text{ } & \rightarrow & \text{ } 78
\end{array}
\]

19. Consider the expression 2 \times 5. Explain how you would help students understand this expression by using two real-world applications of negative integers.

20. A student is looking for all of the factors of 50. She says to you, “My mom said that after I try 1, 2, 3, 4, 5, 6, and 7, I don’t need to test any numbers larger than 7.”

Is her mom correct? Explain why or why not.
Number and Computation Assessment– Version 3  
Diagnostic Teacher Assessments in Mathematics and Science  
Middle School Mathematics

Please provide the following information about yourself:
- Gender: M □ F □  
- Last 4 digits of Soc. Sec. # ________

<table>
<thead>
<tr>
<th>Years of teaching experience:</th>
<th>Gender: M □ F □</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade level(s) currently teaching:</td>
<td></td>
</tr>
<tr>
<td>(Check all that apply)</td>
<td></td>
</tr>
<tr>
<td>Teaching certificate grade level:</td>
<td></td>
</tr>
<tr>
<td>(Check all that apply)</td>
<td></td>
</tr>
<tr>
<td>Teaching certificate content area(s):</td>
<td></td>
</tr>
<tr>
<td>(Check all that apply)</td>
<td></td>
</tr>
<tr>
<td>Number of college math courses:</td>
<td></td>
</tr>
<tr>
<td>0-3</td>
<td>4-6</td>
</tr>
<tr>
<td>The YEAR you received your most recent teaching degree or Rank:</td>
<td></td>
</tr>
</tbody>
</table>

Directions for completing items:
- Please record data and starting and finishing times in the spaces in the upper right-hand corner of this page. It is very important to fill out the demographic information above, especially the last 4 digits of your SSN, as test results will be reported using that as your ID.
- Please answer all questions as completely as possible. Show all work in responding to items and briefly explain your thinking on all items.
- Let the test facilitator know when you are finished. Thank you very much for your time.

<table>
<thead>
<tr>
<th>#</th>
<th>Item</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Which of these statements is FALSE?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>a. Every whole number is a rational number.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>b. Every rational number is a real number.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>c. Every irrational number is a real number.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>d. Every non-terminating decimal represents an irrational number.</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>What percent of 500 is 120?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>a. 60%</td>
<td>b. 24%</td>
</tr>
<tr>
<td>3</td>
<td>Which of the following integers is greater than −5?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>a. 0</td>
<td>b. −50</td>
</tr>
<tr>
<td>4</td>
<td>Which of the following is the least common denominator of 5/8 and 7/10?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>a. 2</td>
<td>b. 4</td>
</tr>
<tr>
<td>5</td>
<td>Which law justifies the equality: 7 × (5 × (8 − 6)) = (7 × 5) × (8 − 6)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>a. associative law of multiplication.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>b. commutative law of addition.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>c. commutative of multiplication.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>d. distributive of multiplication over addition.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Question</td>
<td>Options</td>
</tr>
<tr>
<td>---</td>
<td>------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------</td>
</tr>
<tr>
<td>6</td>
<td>Which point on the number line (a, b, c or d) best represents ( \frac{3}{5} )?</td>
<td><img src="image" alt="Number Line" /></td>
</tr>
</tbody>
</table>
| 7 | Which two rational numbers below are less than \( \frac{2}{5} \)?          | a. \( \frac{1}{4} \) and \( \frac{3}{7} \)  
   b. \( \frac{5}{14} \) and \( 0.41 \)  
   c. \( 0.41 \) and \( 0.14 \)  
   d. \( 1/6 \) and \( 2/6 \)          |
| 8 | The drawing below best represents which of the following expressions?    | ![Number Line](image)                                                   |
|   | a. \( -3 \times \frac{1}{2} \)  
   b. \( -1 \times -3 \)  
   c. \( 3 \times -1 \)  
   d. \( 1 \times -3 \)           |
| 9 | If \( A \) is a negative integer and \( B \) is a positive integer, then the product of \( A \) and \( B \) is always | a. greater than one  
   b. between \( A \) and \( B \)  
   c. less than both \( A \) and \( B \)  
   d. less than or equal to \( A \) |
| 10| Find the three smallest whole numbers such that their least common multiple is 120 and their greatest common factor is 20. | a. 20, 40, 60  
   b. 20, 60, 120  
   c. 1, 20, 40  
   d. 40, 60, 120 |
### Number and Computation Assessment – Version 3

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
</table>
| 11 | Chris Clark, a mathematics teacher, teaches in a special middle school. The school board pays Chris $1 dollar for each second of teaching. Chris teaches (with no breaks) from 8 am until 4 pm each day, Monday through Friday. Chris starts teaching on the Wednesday after Labor Day. This special school observes no holidays.  
   a. Will Chris earn the one-millionth dollar in the morning or afternoon?  
   b. Explain your reasoning. |
| 12 | Mr. Short is four paperclips in height. Mr. Tall is five buttons in height. Two buttons laid end-to-end are the same height as three paperclips laid end-to-end.  
   a. Find the height of Mr. Tall in paperclips.  
   b. Justify your solution. |
### Number and Computation Assessment – Version 3

| 13  | A school’s enrollment increased by one quarter between 1980 and 1990.  
|     | a. If the enrollment in 1990 was 400, what was the enrollment in 1980?  
|     | b. Explain your answer.  |

| 14  | There are two jars each containing chips. In jar A the chips have the following values on them: –9, 3, 7, –5, 8. In jar B the chips have the following values on them: –5, 4, 8, –6, 5. One chip is drawn from each jar and the product of their values is computed.  
|     | a. What chips produce the largest product?  
|     | b. Using your knowledge of integer operations, explain how to solve the problem without actually computing any possibilities.  |
### 15
a. Find the smallest prime number greater than 220.
b. Explain your reasoning in finding the number.

### 16
On a recent quiz, some of the students answered the following multiplication problems as shown.

\[
\begin{array}{ccc}
63 & \times 34 & 54 \\
\times 25 & \times 37 & \times 25 \\
252 & 99 & 126 \\
378 & 231 & 330 \\
\hline
270 & 108 & 378 \\
\end{array}
\]

a. Explain how the students got the wrong answer.
b. What misconception does the students have?
c. How would you help the students correct the misconception?
### Number and Computation Assessment—Version 3

17. Consider a student’s response to the following problem:

**Problem:**
A boy and a girl run equally fast around a track. The boy started first and had run 9 laps when the girl had run 5 laps. When the girl had run 15 laps, how many laps had the boy run?

**Student response:**
This problem is easy. You just set up a proportion and solve it like this:

\[
\frac{9}{5} = \frac{x}{15}; \quad 3 \cdot x = 9 \cdot 15; \quad 3x = 135, \quad \text{so } x = 45.
\]

That means the boy had run 45 laps when the girl had run 15, just like he had run 9 laps when she had run 3.

- a. Is the solution strategy given by the student correct or incorrect?
- b. If incorrect, solve.
- c. Explain your response in terms of proportional and additive thinking.

18. Explain or demonstrate one way to help students understand why: 5/5 + 1/2 = 1 2/5 other than teaching a numerical procedure/process and observing that it results in this answer.
<table>
<thead>
<tr>
<th></th>
<th>Number and Computation Assessment - Version 3</th>
</tr>
</thead>
</table>
| 19 | A student said, “Whenever you subtract two non-zero integers the difference is between the two integers.” This is incorrect.  
   a. Explain if this is sometimes, always, or never correct.  
   b. Use a diagram or model to justify your answer |
| 20 | Students were asked to estimate the answer to $43.654 \div 69 = \ ?$  
   One student looked at the problem and said, “600 for a first estimate, plus 20 makes 620.  
   Explain what the student did mentally to get this answer. |
<table>
<thead>
<tr>
<th>#</th>
<th>Item</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Which of these statements is FALSE?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>a. Every rational number is an integer.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>b. Every fraction is a rational number.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>c. Every real number is either rational or irrational.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>d. Every whole number is a real number.</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>What percent of 550 is 99?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>a. 18%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>b. 5.56%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>c. 5.4%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>d. 55.6%</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Of these integers, −8, 0, −5, −3, which one is the least?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>a. −8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>b. 0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>c. −5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>d. −3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>What is the least common denominator of 5/12 and 7/15?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>a. 30</td>
<td></td>
</tr>
<tr>
<td></td>
<td>b. 60</td>
<td></td>
</tr>
<tr>
<td></td>
<td>c. 3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>d. 180</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Which law justifies the equality:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4 × 7 + 5 × 3 = 5 × 3 + 4 × 7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>a. associative law of addition.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>b. commutative of addition.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>c. commutative of multiplication.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>d. distributive of multiplication over addition.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Question</td>
<td>Options</td>
</tr>
<tr>
<td>---</td>
<td>--------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------</td>
</tr>
<tr>
<td>6</td>
<td>Which point on the number line (a, b, c, or d) best represents $\frac{7}{8}$?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>![Number line diagram]</td>
<td>a. 0.84 and 0.83  \hspace{2cm}  b. 1.31 and 1.32  \hspace{2cm}  c. 1.3 and 1.34  \hspace{2cm}  d. 0.31 and 0.32</td>
</tr>
<tr>
<td>7</td>
<td>Name two numbers between 1/3 and 1/4.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>a. 0.34 and 0.43  \hspace{2cm}  b. 1.31 and 1.32  \hspace{2cm}  c. 1.31 and 1.34  \hspace{2cm}  d. 0.31 and 0.32</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>The drawing below best represents which of the following expressions?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>![Number line diagram]</td>
<td>a. $\frac{-4 \times -2}{2}$  \hspace{2cm}  b. $\frac{4 \times -2}{2}$  \hspace{2cm}  c. $\frac{2 \times -4}{2}$  \hspace{2cm}  d. $\frac{-2 \times 4}{2}$</td>
</tr>
<tr>
<td>9</td>
<td>If A is a negative integer and B is a positive integer, then A – B is</td>
<td></td>
</tr>
<tr>
<td></td>
<td>less than A  \hspace{2cm}  c. greater than B  \hspace{2cm}  b. greater than A  \hspace{2cm}  d. equal to $</td>
<td>A – B</td>
</tr>
<tr>
<td>10</td>
<td>Find the three smallest whole numbers such that their least common</td>
<td></td>
</tr>
<tr>
<td></td>
<td>multiple is 144 and their greatest common factor is 24.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>a. 24, 48, 144  \hspace{2cm}  b. 1, 24, 48  \hspace{2cm}  c. 24, 72, 144  \hspace{2cm}  d. 24, 48, 72</td>
<td></td>
</tr>
</tbody>
</table>
11 Chris Clark, a mathematics teacher, teaches in a special middle school. The school board pays Chris 1 dollar for each minute of teaching. Chris teaches (with no breaks) from 9 am until 4 pm each day, Monday through Friday. Chris teaches 180 days each year.
   a. When will Chris earn the one-millionth dollar? Give your answer to the nearest week, such as 4 years and 12 weeks. (Consider a week to be 5 days of teaching.)
   b. Explain your reasoning.

12 Mr. Short is three paperclips in height. Mr. Tall is seven buttons in height. Two buttons laid end-to-end are the same height as three paperclips laid end-to-end.
   a. Find the height of Mr. Tall in paperclips.
   b. Justify your solution.
<table>
<thead>
<tr>
<th>Number and Computation Assessment– Version 5</th>
</tr>
</thead>
</table>
| **13** The average beginning teacher’s salary increased by one fifth between 1990 and 1995.  
   a. If the average beginning teacher’s salary in 1995 was $24,900, what was the average salary in 1990?  
   b. Explain your answer. |
| **14** There are two jars each containing chips. In jar A the chips have the following values on them: −7, 2, 5, −3, 8. In jar B the chips have the following values on them: −3, 2, −6, −4, 4. One chip is drawn from each jar and the product of their values is computed.  
   a. What chips produce the smallest product?  
   b. Using your knowledge of integer operations, explain how to solve the problem without actually computing any possibilities. |
### Number and Computation Assessment – Version 5

**15**
- a. Find the smallest prime number greater than 390.
- b. Explain your reasoning in finding the number.

**16**
On a recent quiz, some of the students answered the following multiplication problems as shown.

\[
\begin{array}{ccc}
92 & 57 & 43 \\
\times 26 & \times 15 & \times 37 \\
\hline
492 & 285 & 301 \\
164 & 57 & 129 \\
656 & 342 & 430 \\
\end{array}
\]

- a. Explain how the students got the wrong answer.
- b. What misconception does the students have?
- c. How would you help the students correct the misconception?
### Number and Computation Assessment – Version 5

<table>
<thead>
<tr>
<th></th>
<th>Consider a student’s response to the following problem:</th>
</tr>
</thead>
<tbody>
<tr>
<td>17</td>
<td><strong>Problem:</strong> A boy and a girl run equally fast around a track. The boy started first and had run 9 laps when the girl had run 3 laps. When the girl had run 15 laps, how many laps had the boy run? <strong>Student response:</strong> “This looks like a proportion problem but it’s not. Since they are running equally fast the boy will always be 6 laps ahead of the girl – since $9 - 3 = 6$. So, when the girl had run 15 laps the boy would have run 21.”</td>
</tr>
</tbody>
</table>
|   | a. Is the solution strategy given by the student correct or incorrect?  
   | b. If incorrect, solve.  
<p>| c. Explain your response in terms of proportional and additive thinking. |
| 18 | Explain or demonstrate one way to help students understand why $3/4 \times 2/3 = 1/2$ other than teaching a numerical procedure/ process and observing that it results in this answer. |</p>
<table>
<thead>
<tr>
<th></th>
<th>Number and Computation Assessment – Version 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>19</td>
<td>A student said, “Whenever you add two non-zero integers the sum is greater than either integer.” This is incorrect.</td>
</tr>
<tr>
<td></td>
<td>a. <em>Explain</em> if this is sometimes, always, or never correct.</td>
</tr>
<tr>
<td></td>
<td>b. Use a diagram or model to justify your answer</td>
</tr>
<tr>
<td>20</td>
<td>Students were asked to estimate the answer to $43,287 \div 59 = ?$</td>
</tr>
<tr>
<td></td>
<td>One student looked at the problem and said, “700 for a first estimate, plus 20 makes 720”</td>
</tr>
<tr>
<td></td>
<td>Explain what the student did mentally to get this answer.</td>
</tr>
</tbody>
</table>
Appendix D

End of Program Questionnaire

Inspired Math Teacher Numbers & Operations

Earlier this school year, you participated in a Numbers & Operations course. I really need your help to improve this course offering for 2014-2015, will you please share your opinions so the professional development can align to best practices and prove useful to classroom teachers? Participation is completely voluntary and you are free to leave the survey at any point. Thank you for taking a few minutes to complete this brief survey.

* Required

What did you love about the Numbers & Operations course?

What did you like the least about the Numbers & Operations course?

Did the instructor provide opportunities for hands-on learning in the Numbers & Operations course? *
1 indicates the lowest rating; 4 indicates the highest rating
- 1-lowest
- 2
- 3
- 4-highest

How well did the instructor integrate the content of the Numbers & Operations course into your daily school life? *
1 indicates the lowest rating; 4 indicates the highest rating
- 1-lowest
- 2
- 3
- 4-highest

How well did the instructor connect the content of the Numbers & Operations course with other professional learning? *

https://docs.google.com/forms/d/1w3Na75Dd7ZLgQoXv8CNLIHGz5krzCG-qImlH4dE9K9DWSV/viewform
1 indicates the lowest rating; 4 indicates the highest rating

- 1-lowest
- 2
- 3
- 4-highest

How well did the instructor facilitate discussions among the teachers in the Numbers & Operations course? *
1 indicates the lowest rating; 4 indicates the highest rating

- 1-lowest
- 2
- 3
- 4-highest

Is there anything you wished the instructor would have done differently in the Numbers & Operations course?

Which course topic would be most beneficial for K-8 classroom teachers

- Algebraic Concepts
- Data Analysis & Probability
- Geometry
- Measurement
- Mathematical Practices aligned to Common Core State Standards/PA Core Standards
- Teaching to the expectations of the CCSS/PA Core Standards with our current district provided resources

Please feel free to add any additional comments about the Numbers & Operations course that would be helpful in planning future professional development for math teachers.

What grades did you teach in 2013-2014? *

What are the last 4 digits of your social security number? *
I will compare your responses to this survey to the pre-test & post-test results to learn how the style of the class impacted your learning.

Submit
Never submit passwords through Google Forms.
References


(Bertram, 2013). Interview on the results of the Pennsylvania State System of Assessment Results and the Lincoln Intermediate Unit 12 special education population.


Leadership. 66(5)56-60.


Dysell, J. (2012). Interview about the role of intermediary units in state department of education training.


Ferguson, R. F. (2002). What doesn't meet the eye: Understanding and addressing racial disparities in high-achieving suburban schools. Cambridge, MA: Harvard University, John F.
Kennedy School of Government.


Hawley, W. D., & Valli, L. (1999). The essentials of effective professional development:


Pennsylvania Department of Education. (1999). Act 48 Continuing Professional Development
Retrieved from [http://www.portal.state.pa.us/portal/server.pt/community/act_48_-_continuing_professional_education/8622](http://www.portal.state.pa.us/portal/server.pt/community/act_48_-_continuing_professional_education/8622)


Thew, M. D. (2012). Interview on the organizational structure of Intermediate Units.


Weiss, I., & Pasley, J., (2006). *Scaling up instructional improvement through teacher


