INSTRUCTIONAL COACHING AND ITS EFFECTS ON MIDDLE SCHOOL MATHEMATICS TEACHERS’ PERCEPTIONS OF COACHING AND CONTENT KNOWLEDGE: A MIXED METHODS STUDY

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INSTRUCTIONAL COACHING AND ITS EFFECTS ON MIDDLE SCHOOL MATHEMATICS TEACHERS’ PERCEPTIONS OF COACHING AND CONTENT KNOWLEDGE: A MIXED METHODS STUDY

DISSERTATION

A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the College of Education at the University of Kentucky

By

Jamie-Marie (Wilder) Miller

Lexington, Kentucky

Director: Dr. Margaret Mohr-Schroeder, Associate Professor of STEM Education

Lexington, Kentucky

2017

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ABSTRACT OF DISSERTATION

INSTRUCTIONAL COACHING AND ITS EFFECTS ON MIDDLE SCHOOL MATHEMATICS TEACHERS’ PERCEPTIONS OF COACHING AND CONTENT KNOWLEDGE: A MIXED METHODS STUDY

Instructional coaching has been a professional learning opportunity that many school districts have employed to support teacher practice. Pairing instructional coaching with on-going workshops is a relatively new approach to professional development. Participants for this study include fourteen middle school teachers that teach either mathematics or collaborate with special needs students. This study examines the effect that pairing instructional coaching with on-going workshops (with a primary focus on proportional reasoning) has on participants’ content knowledge and their perceptions of coaching. Drawing on Wenger’s community of practice theory and post-modern theory of power, this study employs mixed-methods design. Pre- and post-tests for proportional reasoning were administered to analyze the extent to which content knowledge changed over the course of the study. Pre- and post-interviews were conducted with each participant to determine any misconceptions each had on proportional reasoning and their perceptions of coaching (before and after the study’s instructional coaching). Grounded theory and thematic analysis was employed on the pre-and post-interviews to examine the role that power played in the participants’ perceptions of effective coaching attributes. Results suggest that (a) instructional coaching coupled with on-going professional workshops can change content knowledge in participants; (b) perceptions of coaching can change as the result of experiencing a coaching relationship and (c) power dynamics in the coaching experience determine the extent to which participants see the effectiveness of coaching as a professional development activity.

KEYWORDS: Instructional Coaching, Proportional Reasoning, Professional Development, Communities of Practice
INSTRUCTIONAL COACHING AND ITS EFFECTS ON MIDDLE SCHOOL
MATHEMATICS TEACHERS’ PERCEPTIONS OF COACHING AND CONTENT
KNOWLEDGE: A MIXED METHODS STUDY

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November 21, 2017
DEDICATION

I would like to dedicate this work to my family and friends. Without your love and support, this work would not have been possible. I want to thank God for the opportunity to continue my education and the guidance to lead me to finishing this degree. All things I do to glorify you.
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CHAPTER I

INTRODUCTION

The landscape of education has changed with new content standards and innovative pedagogy. Whether teachers were categorized as seasoned veterans or newly graduated from a teacher preparation program, many have struggled with the content and pedagogy imperative for a dynamic and engaging mathematics classroom. The Common Core State Standards for Mathematics (CCSSM) along with Standards for Mathematical Practice (SMP) call for classroom instruction to focus on teachers assisting students in making connections among several mathematical concepts, represent these connections in a variety of ways and employ critical reasoning skills to verify solutions (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010). These expectations go beyond just simply teaching from a textbook and assigning specific problems for homework. Teachers will need a deeper understanding of content, its vertical progression and how to engage students in mathematical thought and discourse. Due to the change in expectations brought by both the CCSSM and the SMP, teachers may need assistance in meeting the expectations of the CCSSM.

“With the shift to the Common Core State Standards (CCSS) mathematics content, and especially to the mathematics practices, students will need effective intervention strategies” (Hull, Miles, & Balka, 2010, p.41). John Hattie’s research entitled Visible Learning, analyzed approximately 50,000 research articles. The strategy “Response to Intervention” (RTI) ranked third out of 150 influences that bring positive change to student academic achievement (Hattie, 2008). The number of students who are not at grade-level based on the Common Core have pushed classroom teachers to move
instruction away from the traditional paper and pencil approach. The call issued by Shulman in 1986 for teachers to be skilled both in both content knowledge and pedagogy in order to better instruct struggling learners still exists today (Hill, 2009; Hill, Schilling & Ball, 2004).

**Statement of the Problem**

A common mathematical topic that is a stumbling block for many students has been algebra and in particular, proportional reasoning. The Kentucky Department of Education (KDE) requires all students to take both Algebra I and Algebra II in high school (https://education.ky.gov/curriculum/hsgradreq/Pages/default.aspx). An issue that has plagued many middle and high schools has been that students are not prepared to make the leap to algebra. Research indicates teachers still struggle with the connections between number computation and algebraic concepts such as proportional reasoning (Darley & Leopard, 2010). Some teachers view those strands as totally separate topics. As a result, they teach algebraic thinking as isolated skills without making the tie to number, thus making it more difficult for students to learn algebra in later grades (Kieran 1992). Quite often, teachers have a misconception that ratios and fractions are one in the same. However closer examination of ratios and proportional reasoning indicates that this understanding is crucial for later development of understanding of linear functions. Teachers need to be aware of the connections that proportional reasoning holds to future topics in mathematics (Lobato, Ellis, Charles & Zbiek, 2010). In order to assist teachers in the daunting task of bridging number computation to algebraic
reasoning, it was necessary for teachers to engage in more professional
development.

**Purpose of the Study**

There were two purposes for this study. The first purpose was to determine the
effect, if any, that instructional coaching, coupled with on-going workshops, had on the
participants’ content knowledge over proportional reasoning. The second purpose of this
study was to examine the perceptions that participants held about instructional coaching
and its change, if any, on their pedagogy and content knowledge.

**Overview of Timely Mathematical Interventions (TMI) Grant**

The data for this study was gathered from a state Math and Science Partnership
grant. The grant, known as Timely Mathematical Interventions (TMI) was awarded by the
Kentucky Department of Education to the University of Kentucky’s K-12 Mathematics
and Science Outreach Unit. The primary goal was to assist middle school level
mathematics teachers in six districts across Kentucky with integrating research-based
instructional practices into their classroom for Tier I level interventions for struggling
math students. Tier I interventions were defined as:

Tier I is the highly effective, culturally responsive, evidence-based core or
universal instruction, provided to all students in the general education classroom.
General education teachers implement evidence-based curriculum and/or strategies
with fidelity for both academic and behavioral instruction. About eighty percent of
students will succeed with evidence-based curriculum, appropriate instructional
practices and differentiation to teach academic and behavioral content.
(https://education.ky.gov/educational/int/ksi/Documents/KSIRTIGuidanceDocumen
t.pdf, p. 7)

TMI had five, six-hour workshops through the academic year and two sets of two-
day six-hour summer workshops for a total of fifty-four hours of workshops during a
calendar year. This workshop model was conducted for three successive years with teachers receiving approximately 162 hours of workshop support if they participated through the duration of the grant. During these meetings, teachers (both participating and non-participating in this study) were presented the same information and received the same resources/materials. Compensation for all TMI participants (including those in the study) included a stipend for attendance of summer workshops only. Substitute teachers were paid for those TMI participants that attended during the academic year. An important point to note was TMI conducted professional development workshops before this study, but it was only for the duration of this study that proportional reasoning was the focus topic. Topics for proportional reasoning included, but were not limited to, the following: ratios, unit rates, proportions, rate of change and algebraic representations (i.e., tables, graphs, expressions and written situations). Teachers studied these proportional reasoning topics during a series of eight six-hour workshops for a total of forty-eight hours.

Workshops followed a consistent model. For example, each workshop focused on instructional strategies and resources participants could use to teach proportional reasoning. Instructional strategies were first modeled for participants by the facilitators. After a time of modeling, the group debriefed on the positives and barriers the strategy may bring along with how the strategy could be incorporated into the classroom practice. There were usually two to three strategies that were shared throughout the workshop. Various instructional resources were shared during the workshops. Resources included websites, print materials and technology. If print material such as trade books were discussed, participants received a copy of the book to use in their classroom. Websites
and any print material was posted to an on-line share point site that only TMI teachers could access. This on-line library of resources allowed participants to quickly access any resources that were shared in a workshop. Instructional resources were shared with teachers acting as students themselves first. They were asked to think as their students and participate in the lesson as a student. After a time of learning as a student, participants discussed misconceptions their students have that may impede o their learning. Also, specific instructional practices and decisions were discussed that could combat student misconceptions. All teachers were asked to read research on mathematics pedagogy in the form of journal articles or in books as homework. This homework was discussed at the following workshop. Teachers were also asked to practice the strategies with their students in between workshops and bring reflections and student work for analyzing with the group.

**Research Questions**

The explanatory sequential mixed methods study addressed the following research questions:

1. To what extent do middle school mathematics teachers’ content knowledge on proportional reasoning change after on-going workshops and instructional coaching?
2. To what extent do middle school mathematics teacher’s perceptions of instructional coaching change after experiencing a coaching relationship?

**Significance of the Study**

Research has noted that many teachers are weary of change and report lack of support as one of the many reasons why they are resistant to change (Hargreaves & Fullan,
Call from both the National Council for Teachers of Mathematics (NCTM) and KDE suggests teacher support and professional development in the form of mentoring type relationships and professional learning groups to ensure both new and experienced teachers have the resources needed to stay and flourish in teaching (KDE, 2011; NCTM, 2007).

Professional development has long been seen as a strategy to improve teacher content knowledge, thus improving classroom instruction. However, others have seen it as time mandated in meetings that serve no purpose to their teaching. In its truest form, Guskey (2000) provided a comprehensive definition for professional development: “Those processes and activities designed to enhance the professional knowledge, skills, and attitudes of educators so that they might, in turn, improve the learning of students” (p. 16). However, quite often professional development is not content-specific. The typical professional development is an isolated event and not sustained overtime (Hill, 2009).

The lack of sustained professional development that focused on content knowledge and pedagogy has not prepared our teachers for work in the classroom. Hill, Schilling and Ball (2004) explored Shulman’s (1986) work on “pedagogical content knowledge” (p. 9). They found teachers not only needed knowledge of mathematics, but that knowledge had to be more specialized than a non-teacher. Mathematics teachers needed specialized mathematical knowledge “to generate representations, interpret student work, or analyze student mistakes” (Hill, Schilling & Ball, p. 27). Findings suggest that professional development creators need to provide learning opportunities for teachers to gain both the mathematical content knowledge, and the pedagogical knowledge to effectively instruct students (Hill, Schilling, & Ball, 2004). One such professional development practice
considered to provide dynamic or personalized support for teachers was coaching. Coaching occurs when an instructional coach is a partner with teachers to help them incorporate research-based instructional practices into their teaching. They are skilled communicators, or relationship builders, with a repertoire of excellent communication skills that enable them to empathize, listen, and build trusting relationships. (Knight, 2006, p. 30)

The added dimension of personalization sets instructional coaching apart from other professional development. Research conducted recently has examined the effect professional development coupled with instructional coaching has on teachers. Several studies found growth in teacher knowledge and increased instances of student learning when coaching was employed (Alloway & Jilk, 2010; Balfanz, MacIver, & Byrnes, 2006; Becker, 2001).

There has been confusion about instructional coaching, primarily because of its historical roots. Many have pointed to the ideas of mentoring or peer coaching as the precursors to instructional coaching (Joyce & Showers, 1980). With the variety of labels instructional coaching has had, there has been a wide research base for this promising professional development strategy, yet the dynamics between the instructional coach and the teacher have not been examined. This study examined the social phenomenon of “communities of practice” in the development, cultivation and working relationships among participants in workshops and with the researcher in coaching sessions. Further, the negotiation of power in a coaching relationship was investigated through grounded theory and thematic analysis. This approach has often been used in the social sciences, but has had limited use in the field of education. This present study was one of the first to examine teacher perceptions of instructional coaching, communities of practice and the power dynamics of each. To better understand the role a coach can play in transforming
teacher content knowledge and pedagogy, more research on coaching relationships needs to be conducted (Wang & Odell, 2002).

**Theoretical Framework**

For many, the idea of a “coach” has been reserved for those leading individuals or teams in sports. However, the idea of a “coach” has been used in education. In the past twenty years, the idea of an instructional coach (the term, mentor, is also used interchangeably) has become a more prevalent strategy for professional learning in the field of education. Dennen (2004) noted coaching was a form of cognitive apprenticeship. Apprenticeships have existed for hundreds of years to impart mostly vocational knowledge and skills, but cognitive apprenticeships impart a different type of knowledge. Cognitive apprenticeships “promote learning that occurs through social interactions involving negotiation of content, understanding, and learner needs…” (p. 813). Just as the idea of cognitive apprenticeships has been grounded in the age-old practice of vocational apprenticeships, instructional coaching has been grounded in many well-established theories of learning. This study’s theoretical framework used Wenger’s *Community of Practice* (CoP) (1989) along with critical discourse analysis approach to examine the role of power in the coaching relationship and its effects on the change in participant content and pedagogical knowledge and their perceptions of instructional coaching.

**Communities of practice.** Wenger’s social learning theory’s primary focus was on “learning as social participation” and “being active participants in the practices of social communities and constructing identities in relation to these communities” (Wenger, 1989, p. 4). He noted learning is on-going and ever-changing. The four main components
of CoP are: meaning, practice, community and identity. These four components are interdependent upon one another and shaped the work of any CoP.

The component of practice was the key in building and maintaining a CoP. Practice was defined as “way of talking about the shared historical and social resources, frameworks, and perspectives that can sustain mutual engagement in action” (Wenger, 1989, p. 5). It is this concept that could either build or break a coaching relationship. Wenger noted that a unified CoP needed coherence. The three dimensions for coherence of a community were mutual engagement, joint enterprise and shared repertoire (Wenger, 1989).

**Mutual engagement.** The practice exists because individuals choose to engage in ways to negotiate meaning. Individuals need to feel a part of the CoP and agree that diversity in thought is permissible. It is through this interplay among individuals that identity-creation is a unique process for everyone. These identities are interlocked and articulated and perpetuated through mutual engagement, thus a community can be built. It is interesting that Wenger noted the community comes from mutual engagement, not idealized views of the world, meaning that conflict can arise and solidify the community (Wenger, 1989).

**Joint enterprise.** Joint enterprise is defined by the individuals in the CoP. Not necessarily a goal, joint enterprise is negotiated among the individuals in response to their given situated learning experience and world around them. They do not just state a purpose for their work, they mutually-create a purpose for their work as they work together. By creating their purpose as they go, members of the CoP also create mutual
accountability in working toward the agreed-upon purpose. CoPs do not exist in a vacuum, but rather must co-exist in the world and with other CoPs (Wenger, 1989).

**Shared repertoire.** As time continues, the joint enterprise creates avenues of mutual engagement in a CoP. When these two dimensions align, the third dimension of shared repertoire is created. Examples of a shared repertoire included, but are not limited to, routines, words, tools, documents and stories. The products from the shared repertoire remain ambiguous, so as the CoP operates over time and changes purpose, the meaning of those products can be re-negotiated into a new situated learning experience.

The way products from the shared repertoire are created and changed is through reification. Reification is both a process and a product. It is central to CoP work because it is the basis for individuals to project their own meanings of the world, listening to others’ views and then negotiating their shared meanings. It is through these negotiated shared experiences in a situated learning situation that give rise to the tools or objects that a CoP creates (Wenger, 1989). Reification depends upon practice and practice developed by reification. This duality forms the foundation of CoP.

**Conceptual Framework for Instructional Coaching**

The instructional coaching framework used in this study was “Leading for Mathematical Proficiency” (LMP) (Bay-Williams, McGatha, Kobett, & Wray, 2014). LMP was chosen as the conceptual instructional coaching because it helped both the teacher and the coach focus on a specific pedagogical change. The LMP framework examined how the seven “Shifts in Classroom Practice” (Bay-Williams, McGatha, Kobett, & Wray, 2014) can be used to help teachers better plan, prepare and deliver lessons. The
coach and teacher determined areas of growth and focal points for coaching conversations and mathematical topics to further investigate.

The Shifts in Classroom Practice (Bay-Williams et al., 2014) was developed by examining research to determine classroom practices that enable students to learn at higher levels. The seven Shifts in Classroom Practice are as follows:

- From students receiving all the same instruction to differentiated instruction.
- From the students working in isolation to working collaboratively.
- From teacher being the mathematical authority to students’ reasoning being the authority.
- From teacher demonstration to communicating learning expectations.
- From isolated concepts taught to concepts connected.
- From focusing on the right answer to focusing on understanding.
- From math made easy with algorithms to math engaging students in productive struggle.

The coaching cycle begins when the mathematics coach and teacher choose a Classroom Shift to work on in their sessions. The coaching cycle includes three phases: planning, data gathering and reflecting. It was important to note this framework is not a stage model. Coaching does not have to begin in the planning phase, nor does each phase have to be completed each time. This model is flexible in its approach and is dynamic (Bay-Williams et al., 2014).

During planning, the coach helps the teacher to plan a lesson or learn more about a new instructional practice they learned from the TMI workshop they wanted to employ. Both the teacher and the coach work together in the planning phase. The data gathering
phase occurs when the coach collects data via an observation tool. The data collected is agreed upon by both the teacher and the coach. Feedback and reflections from the participants are the data that inform the next coaching phase. Finally, the reflection phase is the most critical. This phase consists of the coach and participant sharing data and insights into the participant’s practice. Insights and an opportunity for growth occurs in this cycle (Bay-Williams et al., 2014).

The seven Shifts in Classroom Practice were beneficial to frame many of coaching conversations in this study because, as research has described, proportional reasoning is often taught by the teacher with students working alone on textbook assignments using algorithms (Lobato et al., 2010). This scenario encapsulated at least three of the Shifts in Classroom Practice (for example, from the students working in isolation to working collaboratively; from isolated concepts taught to concepts connected and from math made easy with algorithms to math engaging students in productive struggle) that needed to be reconsidered when working with a teacher in a coaching situation. Therefore, this coaching framework was beneficial to the current study.

Communities of practice and the links to education and instructional coaching.

Wenger’s theory applies well to the field of education. He noted that “education is not merely formative—it is transformative” (Wenger, 1989, p. 263). Education is a mutual development between individuals and communities that goes beyond socialization and is an investment in the future. There are four dimensions of educational design that Wenger discusses: participation and reification; the designed and the emergent; the local and the global; and identification and negotiability (Wenger, 1989). These four
dimensions tie in well with the LMP instructional coaching framework. Below the four dimensions were outlined with their ties to the LMP instructional coaching framework:

- **Participation and reification**: As stated earlier, this duality shapes CoP. A teacher and their instructional coach works together to examine and discuss products such as textbooks, research-based strategies (mostly from the TMI workshops) and print/media materials to negotiate meaning. Quite often this time, in this particular study, was spent determining purpose for the upcoming coaching sessions. These activities were much like those in the planning stage of LMP.

- **The designed and the emergent**: Teaching and learning are not a “cause and effect” relationship, but rather they are linked by resources and negotiation. This idea is much like the data gathering phase of LMP’s framework. The coach and teacher agree upon the data for collection. Through classroom observation and participant reflection, the information needed for reflection and reification was gathered by the coach and participant for discussion in this particular study.

- **The local and the global**: Creating an environment (whether it be a classroom or coaching session) in which learners have experiences that move them from current knowledge to broaden their knowledge through challenges. In the LMP framework, this is equivalent to the reflection phase in which a participant examines their current practices and how they match the department, school or mathematics education philosophies.
• **Identification and negotiability:** Participant needed resources and materials to determine meaning and, then expound upon, based on social interactions with others in the CoP. This process that Wenger described fit well with the *reflection* phase of LMP in which the coach and participant presented data collected from classroom observations and previous coaching conversations along with content refreshers or new instructional strategies.

**Role of Language.** Wenger’s theory of CoP hinged on the social interaction of individuals and their use of language (whether it be written or spoken) to negotiate meaning. “It is this tight interweaving of reification and participation that made conversations such a powerful form of communication” (Wenger, 1998, p. 62). He further stated, “The communicative ability of artifacts depends on how the work of negotiating meaning is distributed between reification and participation. Different mixes become differentially productive of meaning” (Wenger, 1989, p. 64).

The power of language was critical in the coaching relationship in this particular study. The LMP phases of coaching: *planning*, *data-gathering* and *reflection* all use language to exchange ideas, convey meaning, establish identity and change knowledge. To examine the role that language had in shaping a coaching relationship, the current study employed critical discourse analysis to analyze transcribed interviews, workshop evaluations, observations and coaching sessions. Grounded theory techniques, such as coding, note-taking and thematic analysis, were employed to establish themes and connections to current coaching theories with the data in this study. Applefield, Huber and Moallem (2000) noted that:

Dialogue is the catalyst for knowledge acquisition. Understanding is facilitated by exchanges that occur through social interaction, through questioning and
explaining, challenging and offering timely support and feedback. The concept of learning communities has been offered as the ideal learning culture for group instruction. (p. 38)

Data for thematic analysis in the current study included the following: coded transcripts of pre- and post- semi-structured interviews along with coaching sessions as well as feedback from TMI workshops and coaching notes from classroom observations.

Analysis of discourse in this study focused on “social language” (Gee, 2011b, p. 157) and how it related to the “big D discourse” (Gee, 2011b, p. 176). Social language was “used to enact specific identities and carry out specific sorts of practices or activities” (Gee, 2011b, p. 159). Through these specific identities and practices, discourse took on more than just language. Gee (2011b) notes that there are two types of discourse: discourse with a lower-case d (discourse) and discourse with an upper-case D (Discourse). When looking at discourse, one only examined the written or verbal language. However, when examining Discourse, “words, deeds, values, feelings, other people, objects, tools, technologies, places and times as to be recognized as a distinctive sort of who doing a distinctive what (Gee, 2011b, p. 178). The conventions of social language and Discourse was integral in analyzing the qualitative data from this study because it allowed the researcher to examine the following about language in the coaching relationship: negotiated identities for everyone; constructed knowledge; and the way meaning is attached to knowledge and communication of knowledge.

Power. Power for this study was framed by works from Foucault and postmodernism. Mehta & Ninnes (2003) define postmodernism as “a loosely grouped set of ways of thinking about and analyzing relations between society, social institutions and individuals” (p. 239). Postmodernism is concerned with truth, knowledge and power along with identity-formation (Mehta & Ninnes, 2003). Views on who possesses power
have been questioned. Bloom (1998) noted that “power is situated and contextualized within particular intersubjective relationships” (p. 35). Foucault (1980) went further to say “Power circulates between individuals and that individuals both undergo and exercise power simultaneously and become individuals through the effects of power” (p. 98).

Power has had many meanings based on the context that it was used. For this study, power was equated to knowledge (both content and pedagogical) and its application to classroom instruction. The exchange of these terms fit well with Foucault who noted that the two are linked (Foucault, 1980). Bloome et al. (2008) noted that power takes two forms: product and process. Product is the extent to which a person, group or entity imposes itself by force on another or the amount of resources or goods individuals possess. However, power as a process is defined as a manner in which individuals adapted to situations or created agency for themselves (Bloome et al., 2008). Rogers et al. (2005) note that Foucault along with other postmodern theorists said that interactions were not “based on a system of binaries and static relationships” (p. 368), but rather the fluid social constructs among individuals. This ideology also seeks to understand that the evolution of constructs is a direct by-product of the relationship with power/knowledge (Rogers et al., 2005).

Upon examination of power, Foucault notes that power is best described as “a network of many unequal points or nodes” (Ninnes & Burnett, 2003, p. 281) that do not exert equal power upon each other. This idea of power is synonymous with CoP. Wenger’s four dimensions of CoP (participation and reification; the designed and the emergent; the local and the global; and identification and negotiability) along with power were examined in this study (Wenger, 1989). The researcher first held power by co-
facilitating the TMI workshops on content that a facilitation team agreed upon. The researcher held the power by having access to a variety of strategies and instructional resources that participants may have not had in their schools. Many participants viewed these strategies and resources as something that may help them increase the effectiveness of their classroom practice and expressed an interesting in learning. Participants were chosen by administrators to attend TMI meetings. Administrators expected the participants to attend all the workshops, which did take some of the power of choice away from the participants. For many participants, TMI served as a part of their required PD for the school year.

Power continued to be held by the researcher when classroom observations were conducted. Foucault wrote about disciplinary power in which it was exercised by “observing and measuring individuals, and the normalizing judgements that are made because of these observation and measurements” (Ninnes & Burnett, 2003, p. 282). This disciplinary power was needed for the researcher to gather knowledge about the needs of each participant. Initially, the researcher had power in the coaching sessions, because it was the researcher that made contact with the participant and chose the topics that were covered. The researcher legitimately held the power of how the coaching sessions ran initially because of data gathered from classroom observations and DTAMS pre-test scores. Areas, whether mathematical or pedagogical, that it seemed a participant needed assistance with were worked on in coaching sessions. As the coaching relationship evolved over time, the researcher began to relinquish some of the power in coaching sessions by building a relationship based on open communication and feedback. A plan was tailored to the specific shift they chose in the LMP framework and specific questions
participants had on TMI strategies or content. Over time, participants felt empowered because of the relationship to the researcher and their prolonged involvement with TMI to choose topics for their coaching sessions. Through the course of the study, the power first held by the researcher was then circulated to the participants through the relationships built both in the workshops and in the coaching sessions.

This study’s methodology used interactional data (interviews for this study) needed to investigate the way individuals “resist and transform social relations toward emancipatory ends” (Rogers et al., 2005, p. 384). This study examined the change in perceptions of coaching by interviewing participants before and after they had experienced coaching. Second, this study delved into the coaching relationship formed between the researcher and the participant. With the use of LMP coaching framework and the CoP theoretical framework, this study examined how the coaching relationship and the power between the researcher and the participants shaped their perceptions of the utility of coaching and also the participant agency to change their practice and content knowledge. Finally, it was noted that education researchers were cognizant of the needs and language of marginalized groups (Bloom et al., 2005). The marginalized group in this study were teachers and their desire to have more individualized PD rather than mandated generic PD. The researcher tried to establish characteristics participants valued in their professional learning along with the extent to which participants changed their view of coaching.

**Definition of Terms**

*Communities of Practice (CoP) —* Wenger’s (1989) social learning theory in which individuals reflected upon their own thoughts and reactions to the world and shared with
others in a group. The group collectively worked to gain a common understanding of their world or the task at hand.

*Negotiating of Meaning* — The process of thinking, talking, reflecting and debating to gain understanding and insight of an idea. Negotiating of meaning is completed by both individuals and the CoP as a whole. Both participation and reification are fundamental to the act of negotiating meaning.

*Professional Development*—a meeting or series of meetings provided to teachers on a variety of topics to improve classroom practice or student learning. These meeting(s) are not content-specific and provide generic instructional strategies. Quite often they are lecture-based with little to no active learning on the part of the teacher.

*Reification* — The process by which a group of individuals create meaning and produce products (language, shared stories/histories, documents or objects) that reflect the collective agreement of meaning given a certain situation or time and place. Reification is an on-going process that is integral to the work of a CoP.

*Workshops*—for this study, workshops were a series of eight professional learning opportunities that focused just on proportional reasoning and how to implement math-specific research-based strategies for more effective instruction in proportional reasoning.

**Assumptions**

1. Teachers actively participated in the coaching sessions.
2. Teachers answered questions on each pre-test and post-test of the DTAMS to the best of their ability.
3. Teachers answered interview questions honestly.
4. Teachers took feedback from coaching sessions to make changes to their instructional practices.

**Delimitations**

With any study there are limitations. Three main limitations of this study included the following: sampling of participants, pre-existing relationship the researcher had with the participants and professional development was provided by multiple facilitators. Since it was impossible to work with all middle school mathematics teachers in Kentucky to determine their level of expertise in proportional reasoning and their perceptions of instructional coaching, the teachers who participated in the study were teachers from the TMI grant. This was a small sample of middle school teachers and results from this study lack generalizability due to the smaller sample size.

The study was conducted during year three of the TMI grant. During the first two years, the researcher had been in participants’ classrooms for observations and provided professional development to the participants’ math departments as required by the TMI grant. Although technically there was not coaching, there was a collegial relationship established because the researcher had worked with TMI participants since February 2014. A final limitation of this study was that the researcher was a part of a professional development facilitation team. There were relationships established among the participants and each member of the facilitation team. Therefore, analyzing the effect of on-going workshops along with the instructional coaching was problematic due to the researcher not being the sole person that provided both the professional development and coaching.
Organization of the Study

Chapter I served as the study’s introduction and provided the following information: overview of the TMI grant, statement of the problem, purpose, research questions, significance of the study, theoretical framework, definitions of terms section, assumptions and delimitations. Chapter II provides a review of literature for both proportional reasoning and instructional coaching. Chapter III provides a detailed description of the study’s mixed methods methodology. Chapter IV includes both the quantitative and qualitative results from the data collected by this study. Chapter V includes the researcher’s conclusions drawn from this study along with implications for future research in instructional coaching.
CHAPTER II
LITERATURE REVIEW

This chapter reviews the research literature on teachers’ common misconceptions on proportional reasoning, professional development and mathematics coaching. This review of literature provides the foundation for the research study.

Proportional Reasoning

Proportional reasoning is pervasive throughout the mathematics curriculum. Even though the concepts of ratios and proportions (also known as proportional reasoning) were not explicitly written until the sixth grade in the Common Core State Standards for Mathematics (NGACBP & CCSSO, 2010), the building blocks for proportional reasoning start in earlier grades (Small, 2015). Proportional reasoning is “essential in the study of linear equations, rates, rational numbers and expressions, and similar figures and their area and volume relationships” (Thompson & Bush, 2003, p. 399). Unfortunately, many mathematics teachers, due to lack of training or their own personal misconceptions, have only seen proportional reasoning as a time to apply an algorithm for “cross multiplication” and often do not have the understanding to adequately teach proportional reasoning in a variety of contexts (Lobato, Ellis, & Zbiek, 2010).

The main curricular focus during this phase of the TMI grant was proportional reasoning for two reasons. First, formative assessment of TMI participants during years 1 and 2 of the grant revealed proportional reasoning was a topic many admitted they had difficulty in teaching and understanding what the Common Core Standards outlined. Second, proportional reasoning has often been quoted as one of the most difficult concepts for students to understand and teachers to instruct (Thompson & Bush, 2003).
Proportional reasoning is seen in the mathematics curriculum from elementary to secondary. Often students and teachers alike believe that proportional reasoning is just the process of setting up two ratios that are equal in order to find a missing quantity. Proportional reasoning is the underpinning conceptual knowledge needed to correctly master other mathematical skills. Research often notes that proportional reasoning is such an integral concept for students to understand, it is often a gatekeeper concept to understanding secondary mathematics (Lamon, 2003; National Council of Teachers of Mathematics (NCTM), 2000). Since proportional reasoning is a foundational mathematical skill that is important for students to know, then it is imperative teachers have knowledge of both pedagogy and content to adequately instruct students. Unfortunately, studies have shown that teachers (pre-service, intern and practicing) lack the content knowledge needed to understand, let alone instruct students, on proportional reasoning (Simon & Blume 1994).

To address this issue, a long-held teacher intervention coupled with a relatively new intervention could provide support for those teachers who are struggling with proportional reasoning instruction. This study examined the effect that PD, coupled with support from a mathematics coach, changed teachers’ pedagogical and content knowledge needed to help students gain a better understanding of proportional reasoning. Thompson and Bush (2003) noted that “proportional reasoning is a way of thinking, not an algorithm to be used in solving problems” (p. 400). NCTM (2000) noted that middle school students need to be “proficient in creating ratios to make comparisons in situations that involve pairs of numbers” (p. 34). However, they go further in their Principles and Standards for School Mathematics to describe that proportional reasoning uses multiple representations
such as number, tables, graphs and equations, to relate quantities (NCTM, 2000).

Proportional reasoning is the foundational knowledge for other middle school mathematical topics such as: percentages, scale factors, dilations, scale drawings and probability. Further, proportional reasoning is critical in helping middle school students understand the relationship between the circumference of a circle and its diameter. And even still, proportional reasoning is integral in middle school students understanding of linear relationships (NCTM, 2000).

Although NCTM noted that proportional reasoning was pervasive in the mathematics curriculum, other research has shown that most proportion problems were presented as word problems (Tourniaire & Pulos, 1985). Two of the most common categories of proportional reasoning were rate and mixture problems. Rate problems pushed students to compare the ratios of different objects being measured in different units. Mixture problems also compare differing quantities like rate problems; however, mixture problems investigate the concentration of a new object created from the mixing of two or more substances usually measured in the same units. A classic example is mixing orange juice with water to make a weaker orange drink (Tourniaire & Pulos, 1985).

There has been a dichotomy created with mathematics standards saying that proportional reasoning is used in several areas of mathematics yet, students are often seeing proportional reasoning exemplified as word problems with limited context. Textbooks have not helped in this situation because many treat proportional reasoning as solving proportions (Lobato, Ellis & Zbiek, 2010). Therefore, students have tried to apply an algorithm to derive an answer, but do not have the reasoning to apply to a variety of
contexts. This dichotomy is one of the many reasons why proportional reasoning is often problematic for both students and teachers (Lobato, Ellis, & Zbiek, 2010).

**Studies on misconceptions in proportional reasoning.** Misconceptions abound with proportional reasoning. A common one perpetuated by teachers in many classrooms instructing students was the following: If you see a word problem with three numbers and one is missing or you see the keywords of *per*, *rate* or *speed* then it is a proportion problem (Lobato et al., 2010). Two areas that have been problematic for both teachers and students have been: proportional reasoning is an additive process not a multiplicative process (Clark & Kamii, 1996; Simon & Blume, 1994) and slope is not a form of proportionality (Lobato & Thanheiser, 2002). Overcoming these misconceptions can be accomplished by assisting teachers to change their pedagogy and increase their content knowledge so they can provide effective learning experiences that can help students better understand proportional relationships.

A misconception many students and teachers (both pre-service and practicing) hold is that proportionality is an additive process because many do not understand the meaning of multiplication. Clark and Kamii (1996) studied the responses of 360 first- through fifth-grade students. The study found that at its highest level for any grade level, only 48% of the fifth grade used multiplicative thinking to solve the tasks. Results such as those were understandable with young students, but Simon and Blume (1994) found similar results when studying 26 pre-service teachers. On the pre-test, 19 out of 26 pre-service teachers still employed additive thinking. In the Simon and Blume (1994) study, two units on proportional reasoning were taught to the pre-service teachers that included: multiplicative relationships and modeling real-world situations. Special consideration was
paid to how pre-service teachers worked on tasks, participated in discussions, and employed metacognition (thinking about their mathematical reasoning) to gain a better insight about multiplicative relationships and modeling. There were interesting findings with implications for preparing pre-service teachers. First, it was found that usual mathematical content seen in school did not make connections with proportional reasoning. Additionally, there was a procedural emphasis placed in classroom instruction and mathematical modeling was under-utilized. Second, if classroom instruction used traditional modes of lecture and demonstration, then the proportional reasoning skills of students were not fostered. It was noted that classrooms need to push students to test the validity of their mathematics and not just finish another problem set. This push for validation and reasoning needs to start in elementary school with more emphasis on mathematical modeling. In order to meet this push, pre-service teachers should take more mathematical courses and also be taught using methods described in this study (Simon & Blume, 1994).

Lobato and Thanheiser (2002) examined the misconception that slope did not use proportional reasoning. In this study, it was first asserted that textbooks have some blame to the misconception of slope. Textbooks tend to define slope as “direction or steepness of a line” (p. 162), however there is more to slope than this simple definition. In this study, high school students were faced with the challenges of determining the slope of wheelchair ramp and determining how fast a person could walk. In either case, students struggled to form ratios. Instead of teaching the cross-multiplication algorithm, the researchers worked with the students in activities that fostered proportional reasoning and connected real-world scenarios and modeling. Modeling was facilitated with technology
through a variety of computer programs. Students deduced the meaning of slope by examining numeric patterns they saw in the data they generated. The researchers concluded that students need to learn about slope in real-world terms (even if the numbers are messy). Instructional activities can help students to achieve this goal (Lobato & Thanheiser, 2002). If students and pre-service teachers learned proportional reasoning better with real-world context and modeling, then it would stand to reason that practicing teachers should have PD that emulated these same research findings.

Research has shown that the traditional manner of instructing proportional reasoning is not the best way for students to learn and understand it (Clark & Kamii, 1996; Labato & Thanheiser, 2002; Lobato et al., 2010; Tourniaire & Pulos, 1985). Rather research suggests that methods other than lecture and demonstration can be beneficial to students. Allowing students to try strategies on their own and grapple with their reasoning is better than just telling them the algorithm (Clark & Kamii, 1996; Lobato et al., 2010). Tourniaire and Pulos (1985) noted the following: “Proportional reasoning should be considered as a multi-faceted activity, and presented as such. Different methods may be necessary to teach proportional reasoning for different number structures and different contexts” (p. 200). Therefore, teachers need to employ methods they may or may not have seen as a student or in teacher preparation programs. This gap in pedagogical and content knowledge can be filled with use of PD and mathematics coaching.

**Professional development**

There are many definitions of PD. One offered by Guskey (2000) notes that PD is “those processes and activities designed to enhance the professional knowledge, skills, and attitudes of educators so that they might, in turn, improve the learning of students” (p. 16).
However, the content and manner of PD delivery is changing. Each year schools offer PD opportunities to their teachers. However, research shows many PD opportunities are merely isolated events that are not content-specific (Hill, 2009). Therefore, there have been calls from local and national educational agencies to provide better support to teachers (KDE, 2014; NCTM, 2007). One such support was the idea of instructional coaching. Research has shown that both pedagogical and content knowledge increases after working with an instructional coach (Kretlow, Wood & Cooke, 2009; Polly, 2012; Rudd et al., 2009). Coupling PD with an instructional coach’s support could help alleviate some misconceptions teachers have had about proportional reasoning or any other mathematical topic.

Research has shown some characteristics of high quality PD. Garet, Porter, Desimone, Birman, and Yoon (2001) completed an exhaustive literature review of studies on PD and found the following characteristics of high quality PD: content focus, active learning, coherence, collective participation, and duration. These characteristics form a framework in which PD can be delivered to teachers in an effective manner. Further explanations of these characteristics follow:

- **Content focus**—PD sessions align their activities and content to how students learn mathematics, pedagogy that supports student learning and increasing teacher content knowledge.

- **Active learning**—PD sessions that involve teachers in discussions, examining student work, and participating in hands-on-activities fits this description. Teachers are not subjected to the “sit and get” model often associated with traditional PD.
• **Coherence**—PD sessions present information consistent in two manners: first, with the teacher’s belief system and content knowledge; and second, with policies and procedures of the local and state school systems.

• **Collective participation**—PD sessions involve teachers from the same grade level, school or district. Although this was not implicitly stated, this type of PD could also mean a cohort of teachers involved in grant work that meet as a group often (as seen in TMI).

• **Duration**—PD sessions meet more than once. Research shows there may be no exact “tipping point” of how many hours is optimum for a teacher’s increase in content knowledge or change in practice. However, Yoon, Duncan, Lee, Scarloss, & Shapley (2007) reported that professional development lasting fourteen or fewer hours showed no effect on student or teacher learning, whereas programs offering more than fourteen hours of sustained, content-focused professional learning showed significant positive effects. Professional learning opportunities that worked with teachers between 30 and 100 hours over a minimum of six to twelve months had the greatest effects.

The study mentioned above was conducted over a decade ago, however, their findings are still timely. The TMI workshop model used for this study set out to meet as many of the aforementioned characteristics of effective PD. Organizations such as the NCTM and Kentucky Department of Education (KDE) have used these characteristics to provide more insight and oversight of how PD should be handled and delivered to mathematics teachers.
NCTM published a book entitled *Mathematics Teaching Today* (2007) that outlined standards for teachers’ practice, supervision and continued professional growth. Agents that were to oversee these standards included the teachers themselves along with college and university teacher preparation programs and the school districts. NCTM wants mathematics teachers to move away from the “tell, show and follow my lead model” (p. 151) and move more into using pedagogy that fosters group work, mathematical discourse, modeling, multiple representations, examining student work and multiple forms of assessment. Teachers need to know not only content but how students learn that content. Connections should abound in the mathematics classroom. Examples include connections among mathematical concepts; between mathematics and other disciplines; and with technology. NCTM also outlines the responsibilities for schools and school districts on how to implement these changes in PD. One of the suggestions is “providing mentoring and support system for beginning and experienced teachers of mathematics to ensure that they grow professionally and are encouraged to remain in teaching” (p. 174). Although not explicitly stated, this suggestion seems to make the call for mathematics coaching.

KDE is looking to help change the face of PD with its selection by Learning Forward to be a demonstration state in the “Transforming Professional Learning to Prepare College-and Career-Ready Students” in October 2011. The results of this task force’s work were a written set of standards for PD for the Commonwealth. This set of standards moved from calling the teacher meetings PD to calling it professional learning. It was noted that Kentucky wanted to restructure teacher growth from PD meetings and isolated workshops to professional learning communities that focus on a variety of topics
chosen by teachers or driven by student needs based on data. Professional learning is job-embedded and on-going. The content of the professional learning activities is planned and facilitated by educators in-house or by outside agencies. One of the specific activities highlighted for professional learning is coaching (KDE, 2014).

Current trends show that the mathematics education field understands that mathematics instruction is complex and dynamic (Lobato et al., 2010; NCTM, 2007). To ensure pre-service and practicing teachers have the support needed to face the demands of teaching mathematics, coaching has gained recognition as a potential intervention that could complement PD.

Mathematics Coaching

Quite often the terms mentoring and coaching are used interchangeably. Origins of mathematics coaching came from mentoring research. Of course, the term “mentor” can be traced back to the time of ancient Greeks and the *Odyssey*; however, Levinson (1978) brought the idea to the education field. He purported that mentors “several years older, a person of greater experience and seniority…to mean teacher, advisor or sponsor” (p. 97). Joyce and Showers (1980) began using the term “peer coach” to describe the interaction of one teacher helping another. Throughout the years, coaching in some form has been gaining momentum as a means of delivering PD to teachers in a more personalized manner. This is a direct response to schools needing help with how to best instruct students in mathematics so their achievement will increase (Alloway & Jilk, 2010; Campbell & Malkus, 2013b). Murray et al. (2009) noted research by Joyce and Showers (2002) that peer coaching is applicable to PD as an intervention and provides the
opportunity for teachers to improve their knowledge and skill which will transfer to the classroom.

It seems that mathematics coaching paired with PD is such a new intervention in teacher professional development that the body of research is still trying to establish coaching as a viable option for schools to employ. Research has determined the roles and identities that coaches assume (Becker, 2001; Campbell & Malkus, 2013a; Chval et al., 2010; McGatha, 2008) positively impact teacher pedagogical and content knowledge (Kretlow, Wood & Cooke, 2009; Polly, 2012; Rudd et al., 2009) and reiterated that effective coaches were knowledgeable coaches that need continued PD themselves (Campbell & Malkus, 2013a, 2013b; Evertson & Smithe, 2000).

There have been many titles for coaches such as mentors or specialists. This disjointed nomenclature has hurt the research for coaching. Campbell and Malkus (2013a) noted that schools are hiring mathematics coaches and mathematics specialists to help raise student achievement in mathematics. However, they note that “elementary school mathematics coaches focus on working with individual teachers to foster instructional change; specialists are also expected to advance a school’s mathematics program” (p. 199). If one assumed that terms “specialist” and “coach” are synonymous, then the Campbell and Malkus (2013a) research showed that student achievement was affected when a mathematics specialist is assigned to a school. In this three-year study, 36 elementary schools were involved. One-third of the schools were assigned a mathematics specialist for all three years; another one-third of the schools were assigned a mathematics specialist for only one year; while the remaining one-third of the schools did not receive any mathematics specialist. Mathematics specialists had additional training beyond their
teacher education courses that included five mathematical content courses and two leadership courses. Mathematics specialists went into classrooms and directly assisted individual teachers. After three years, results show that those schools who had a mathematics specialist statistically significantly out-performed those schools that did not have an assigned mathematics specialist on student achievement measures. However, when looking deeper into the results, it was found that those schools who had a mathematics specialist for only one year did not significantly outperform those schools who did not have a mathematics specialist on student achievement measures. These outcomes, it was reasoned, were because it took time to establish a mathematics specialist’s position in the school.

Another study examined student achievement coupled with coaching (in this case peer coaching) was conducted by Murray, Ma and Mazur (2009) and examined the effectiveness of a program known as the Mentored Implementation Program. This program had two facets of PD: first, an intensive two-week summer PD followed by peer coaching through the following school year. To study the effects of coaching and student achievement, there were two groups of Mentored Implementation Program teachers created. One group received peer coaching (experimental group) while the other group did not receive peer coaching (control group). Data collection included quantitative measures of pre- and post-tests of students in both the experimental and control teacher classrooms. Qualitative data was collected on the teachers’ thoughts on coaching and of the post-observation conferences. Results concluded there were no statistically significant differences between the students’ pre- and post-test scores.
It was noted in this study that “one teacher is not viewed as more of an expert than the other. Instead, they work in a partnership.” (Murray et al., 2009, p. 204). Also, the only requirement stipulated on coaching was that it needed to occur at least two times during a school year. This study could have been promising to glean more information on the effects of coaching on student achievement, but this study falls short when compared to the coaching models described earlier. For example, the use of “peer coaching” was not an appropriate description because in the Mentored Implementation Program, extra training for the coaches was not included. Past research has included characteristics of successful peer coaching to include training for the coaches (Campbell & Malkus, 2013a, 2013b; Evertson & Smithey, 2000). Further, peer coaching may not bring the impact to increasing teacher knowledge of content and pedagogy that a coaching or specialist model can bring because often peer coaches do not receive the continued training that coaches or specialists receive (Bruce & Ross, 2008). If teacher knowledge of content and pedagogy is not increased, more than likely student achievement will not increase as well. Additionally, it is questionable whether a coaching model was even created if the peer coaches only were required to meet twice during the school year.

**Conclusions**

Teachers struggle with instruction on proportional reasoning because often how they were taught as students (Clark & Kamii, 1996; Labato & Thanheiser, 2002; Lobato et al., 2010; Tourniaire & Pulos, 1985) along with their teaching materials (Lobato, Ellis & Zbiek, 2010) do not support the depth to which the Common Core requires teachers to instruct and understand the vertical progression of proportional reasoning (NGACBP & CCSSO, 2010). PD coupled with instructional coaching could be an intervention to
support teachers in changing their instruction of proportional reasoning along with their overall practice. However, it is imperative to note that traditional PD which is often isolated events and does not focus on specific content and pedagogical practices is not enough (Hill, 2009). Local and national educational agencies (KDE, 2014; NCTM, 2007) note that both pedagogical and content knowledge increases after working with an instructional coach (Kretlow, Wood & Cooke, 2009; Polly, 2012; Rudd et al., 2009).

Work with a coach coupled with PD that exhibits characteristics of high quality (content focus, active learning, coherence, collective participation, and duration) (Garet, et al., 2001) could impact teacher knowledge and practice. This study took the research on proportional reasoning instruction, PD and instructional coaching to examine the effects, if any, that coupling a workshop model along with instructional coaching to see the effect it had on teacher content knowledge and pedagogy along with the perceptions teachers had on instructional coaching.
CHAPTER III  
METHODOLOGY

The research design employed for this study was an explanatory sequential mixed methods study. There were two purposes for this study. First, the purpose of this study was to determine the effect, if any, that instructional coaching, coupled with on-going workshops, had on the participants’ content knowledge of proportional reasoning. Second, the purpose of this study was to examine the perceptions that participants held about instructional coaching and its change, if any, on their pedagogy and content knowledge.

Mixed Methods Research Design

Mixed methods research has provided very promising results in the field of educational research. One of the reasons was its growth noted by Johnson and Onwuegbuzie (2004), “The goal of mixed methods research is not to replace either of these approaches but rather to draw from the strengths and minimize the weaknesses of both in single research studies and across studies” (p. 14-15). The researcher saw the promise that mixed methods research had for gaining a deeper understanding about teachers’ content and pedagogical knowledge and embraced it as the methodology for this study.

A diagram, on the following page, of the explanatory sequential mixed methods design in Figure 3.1 outlined the methodology for this study.
Figure 3.1. Explanatory sequential mixed methods design (adapted from Creswell, 2015, p. 60).

The design was sequential in that the quantitative and qualitative data collection occurred in two distinct phases. The quantitative data was first collected with the administration of the Diagnostic Teacher Assessment in Mathematics and Science (DTAMS) followed by a qualitative data collection in the form of semi-structured interviews that asked participants to explain how they answered specific mathematics
questions from the DTAMS. The explanatory sequential design set out to provide the story of the how and why to the numeric data (Creswell, 2014). This design was chosen for the current study because the purposes of the study were to determine the effect, if any, that instructional coaching, coupled with on-going workshops, had on the participants’ content knowledge of proportional reasoning, along with an examination of the perceptions that participants held about instructional coaching and its change, if any, on their pedagogy and content knowledge. By only administering the DTAMS, the study would only determine if teachers gained content knowledge by simply examining if post-test results were higher than pre-test results. However, the extent to which workshops paired with instructional coaching affected the change in pre-test to post-test scores would not be fully examined if qualitative measures of examining the richness and depth of their answers were not employed.

Just like in traditional sequential designs, the quantitative results from the DTAMS were used to inform the researcher of specific items that participants missed on proportional relationships along with those items that reflected the content taught in the on-going workshops. Selected items were included in the semi-structured interview protocol for participants to answer. Unlike the traditional sequential design of two distinct phases, there was an intervention phase that occurred between Phase 1 and 2. The intervention phase included the researcher actively working with participants both in on-going workshops and instructional coaching sessions (both in-person and online). During the intervention phase, data collected included the following: coaching notes from classroom observations, field notes from coaching sessions and workshop feedback sheets from monthly TMI meetings.
Participants

The recruitment of participants for this study came from those teachers who have been a part of the TMI grant which began in February 2014 was administered by the K-12 Mathematics and Science Outreach Unit. Selection of participants used criterion sampling in which each participant had to meet the following two criteria: (a) an active TMI participant, meaning regular attendance to monthly math workshops; and (b) currently has a middle grades certification in either mathematics or special education. Some participants had a high school teaching certification. Data collected on those participants were not used for this study but could be included in future research studies. Initially, the TMI grant had 30 middle and high school mathematics teachers from a total of six school districts in central and eastern Kentucky.

Teachers in TMI had the option of participating in the data collection process or waiving their participation at no penalty. In July 2015, TMI teachers were made aware of the study at a summer meeting and viewed a power point presentation (Appendix H) that gave an overview of the tasks they would be asked to perform, data that would be collected and the benefits that participation in this study could bring to both themselves and the education field. There was a second call for participants at the August TMI meeting for those TMI participants unable to attend the summer meetings or were new to the TMI grant.

In August 2015, there were 23 participants in the study. However, five TMI participants terminated their participation. Three participants dropped due to their district ending partnership with the grant, while two participants dropped due to a change in their
teaching assignments that kept them from attending the workshops. This study collected
data from 18 participants, however there were 14 that met the criteria.

Demographics include the following for the participant pool: 4 males (28.6%) and
10 females (71.4%); 13 Caucasians (92.8%) and 1 African-American (7.1%); 12 regular
education teachers (85.7%); and 2 special education collaborators (14.2%). The
participants’ years of experience ranged from 0-20 years with a mean of 6.7 years and a
standard deviation of 6.4 years.

Below is a table that list each participants’ pseudonyms, years of teaching
experience (by interval), number of years in TMI prior to the study (0-2) and number of
times they attended the TMI workshops (out of 8):

Table 3.1

<table>
<thead>
<tr>
<th>Pseudonym</th>
<th>Years of Teaching Experience</th>
<th>Number of Years in TMI (0, 1, 2)</th>
<th>TMI Attendance of Workshops (out of 8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cara</td>
<td>4-7</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>Marie</td>
<td>0-3</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>Sasha</td>
<td>4-7</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>Mark</td>
<td>4-7</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>Madelyn</td>
<td>0-3</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>Ellen</td>
<td>8-11</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Derek</td>
<td>0-3</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>Rose</td>
<td>20-23</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Linda</td>
<td>0-3</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>Eli</td>
<td>12-15</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Samantha</td>
<td>0-3</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Jason</td>
<td>0-3</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>Stella</td>
<td>4-6</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>Karen</td>
<td>16-20</td>
<td>2</td>
<td>4</td>
</tr>
</tbody>
</table>
**Instrumentation**

Four instruments were used to collect data for this project: the DTAMS with a focus on algebraic reasoning, two semi-structured interview protocols and TMI Classroom Observation Instrument (See Appendix J). The first interview protocol was a pre-interview protocol along with a classroom observation using the TMI Classroom Observation Instrument were administered before the on-going workshops and instructional coaching on proportional reasoning was introduced. A post-interview protocol along with a classroom observation using the TMI Classroom Observation Instrument were administered after the workshops on proportional reasoning were completed.

**Diagnostic teacher assessments in mathematics and science.** The first instrument administered was the DTAMS from the University of Louisville’s Center for Research in Mathematics and Science Teacher Development. The DTAMS included the following four domains: number and computation; geometry and measurement; probability and statistics and algebraic ideas. For this study, the domain assessment for algebraic ideas was administered to all participants. DTAMS had a total of 20 items with 10 multiple-choice items and 10 open response items. The DTAMS measured the following four types of mathematical knowledge:

Knowledge Type I: memorized/factual knowledge

Knowledge Type II: conceptual understanding

Knowledge Type III: reasoning/problem-solving

Knowledge Type IV: pedagogical content knowledge (see Appendix A for a more detailed description).
Five items were written for each of the four types of mathematical knowledge. Content for the algebraic ideas domain assessment included the following three categories: (1) patterns, (2) functions relationships, (3) expressions, polynomials and formulas and (4) equations and inequalities.

The DTAMS test has been subjected to a series of tests to determine its reliability and validity. University of Louisville determined validity by creating the DTAMS in three phases. The first phase was to confer with national standards and research on common mathematical misconceptions that middle school students harbor. The second phase included mathematicians, teacher educators and middle school math teachers to create prototype assessments. Finally, a national review panel verified these tests did measure the intended content. Reliability was determined by administering the DTAMS to teachers who had participated in professional development, courses or currently taught middle school mathematics. The following reliabilities were established through this process: internal, equivalency and inter-scorer (Saderholm, J., Ronau, R., Brown, E. T., & Collins, G., 2010). Two different versions of the DTAMS were administered to the study’s participants as a pre-test and post-test to measure the change in content knowledge before and after participants engaged in continuing professional development in teaching proportional reasoning over an eleven-month period that paired on-going workshops with instructional coaching.

**Semi-structured pre-interview protocol.** The second instrument administered to participants was a semi-structured pre-interview protocol that gathered participants’ perceptions of instructional coaching and experiences, if any, with instructional coaching and professional development thus far in their professional careers. There were two
versions of the pre-interview protocol. One version was for those participants that noted they had experience with an instructional coach (see Appendix B) and a second version for those who did not have experience with an instructional coach (see Appendix C).

A literature review on instructional coaching was conducted by the researcher to gather a sense of an instructional coach’s roles, identities and duties as evidenced by current studies (Becker, 2001; Campbell & Malkus, 2013a; Chval et al., 2010; McGatha, 2008). Also, the researcher examined the role of professional development and what attributes constitute high quality professional development (Guskey, 2000; Garet et al., 2001). The researcher also found organizations such as the National Council for Teachers of Mathematics (2007) and the Kentucky Department of Education (2014) that called for more incorporation of instructional coaching as a means of professional development for teachers.

Because of the literature review, the researcher formulated questions that would gather data to examine the extent to which participants in this study had similar perceptions and expectations of instructional coaching that were seen in current studies. Patton (2002) notes that question formation was important in developing an interview protocol and suggested several types of questions. The researcher used his suggestions of open-ended questions that focused on experiences and values. Careful consideration was given to the wording so that leading questions were not formulated but rather presupposition questions were included so that participants could give both positive and negative statements to a topic in the interview. The pre-interview protocols were vetted through a pilot study for clarity. Additionally, participants were asked five DTAMS items selected by the researcher that assess proportional reasoning from the algebraic
ideas domain assessment to gather base-line data on participants’ knowledge of proportional reasoning.

**Semi-structured post-interview protocol.** The third instrument administered was the post-interview protocol (see Appendix D), which was administered after an eleven-month period in which participants had the opportunity to attend eight workshops and receive instructional coaching. The purpose of this post-interview was to determine the change, if any, in content knowledge after the professional development experience that employed both on-going workshops with instructional coaching and examined if the participants’ perceptions of instructional coaching had changed as a result.

Questions for the post-interview protocol were like the pre-interview in their construction; however, there was an added dimension to a question. The researcher analyzed the participant responses from the pre-interview in which they were asked what attributes an effective instructional coach possessed. The top ten commonly named attributes were listed on a piece of paper and given to the participants (see Appendix E). Participants were asked to choose three attributes they felt were most important for an effective instructional coach to possess and describe their importance.

As with the pre-interview, participants were administered five DTAMS-aligned items from the algebraic ideas domain assessment. The purpose of this portion of the interview protocol was to determine if there had been any change in their content knowledge on proportional reasoning during the eleven-month intervention period.

**TMI classroom observation instrument.** The fourth instrument administered was the TMI Classroom Observation Instrument (see Appendix J). This instrument was created for the TMI grant as a means to collect data for reporting grant status to KDE.
The TMI classroom observation instrument was created by a team that included the workshop facilitators and the grant’s external evaluator. It was created by the team selecting particular items that were congruent to TMI’s objectives from a data base of observation tools that the University of Kentucky’s K-12 Mathematics and Science Outreach Unit had on file. This classroom observation instrument is not validated. Content of the instrument included the instructional practices TMI covered in workshops, technology/manipulative use, level of questioning and discourse along with implementation of the SMPs. The TMI Classroom Observation Instrument utilized both a check the box and antidotal notes sections for data collection. This study used the data from the TMI Classroom Observation Instrument to inform the content taught at workshops and reiterated in coaching sessions. It also served as a data point for qualitative analysis in examining how teacher practice (e.g. instructional grouping, classroom discourse and integration of TMI strategies) changed before to after the study.

**Contributions of the pilot study**

A pilot study of the interview protocol was conducted in the Spring 2015 as a mini-research project for a Fields Study graduate course. Four participants were included in the pilot study. There were two interview protocols vetted in the pilot study: one for those participants who have not experienced instructional coaching and one for those participants who have experienced instructional coaching. Two participants were interviewed with the “not coached” protocol, while the other two were interviewed with the “coached” protocol. The purpose of the pilot study was to determine if the line of questioning would provide responses that yielded perceptions, feelings and misconceptions that the participants held about instructional coaching. Changes were
made in the wording of some of the interview questions. The researcher noted there were no questions about participants’ thoughts on PD. Questions were added to the interview protocol to collect data for Research Question 1.

The pilot study did not focus on any mathematical topic. However, the researcher found that interviewing participants garnered a level of data collection in which participants’ thoughts and feelings could be analyzed. The researcher thought content knowledge could be analyzed at a deeper level if participants spoke about their solution path on math problems. Therefore, the researcher decided to include mathematical questions that aligned with selected proportional reasoning questions on the DTAMS during the interview. Participants’ answers were audio-recorded and analyzed based on correctness, vocabulary usage and attention to multiple representations to gain a better understanding of the conceptual knowledge and any misconceptions that participants held on proportional reasoning.

Collection of Data

Approval for this study was granted by the University of Kentucky’s Institutional Review Board through the Office of Research Integrity before data collection on May 27, 2015 (see Appendix F) with a continuation granted on April 8, 2016 and March 8, 2017. A call for participants was made during the summer workshop at the beginning of the TMI grant Year 3 in July 2015. All TMI teachers viewed a Power Point presentation by the researcher that outlined the purpose and design of the study (see Appendix H). Each TMI teacher was provided a copy of the informed consent letter (see Appendix I). The researcher carefully covered the informed consent letter and fielded any questions with the group. It was emphasized that non-participation in the study would not have any
negative effects on continuing with the TMI grant. Also, if participants wanted to terminate participation in the study, they could do so without termination from the TMI grant project. Once written consent was obtained, the DTAMS was administered to all TMI teachers regardless of participation in the study to fulfill grant requirements. DTAMS scores for the study participants were considered pre-test scores. Each TMI teacher was given 75 minutes to complete the DTAMS. Another call for participants along with another DTAMS administration was made in August 2015 due to new teachers taking the place of TMI teachers who left the grant project.

During the months of August and September 2015, the researcher conducted classroom observations with the TMI Observation Instrument (see Appendix J) and conducted the semi-structured pre-interview that was audio-recorded for later transcription. At the time of the pre-interview, participants chose an Instructional Shift (see Appendix K) that would lead the coaching sessions that occurred between August 2015 and July 2016. Coaching sessions were set up at the participant’s convenience via email. The researcher coached the participants both virtually (fielding email questions/concerns and sharing resources participants felt were needed) and in person (face-to-face meetings and co-teaching). The researcher took field notes over each coaching session that included the topics covered, resources shared, participant’s new learning, perceived impact on pedagogy and next steps for both the participant and researcher to continue the coaching relationship.

Those participants that attended the on-going workshops were asked to fill out feedback forms (see Appendix L) at the end of each workshop that guided the researcher and the TMI facilitation team on topics in proportional reasoning the participants wanted
to learn about in upcoming workshops and any concerns about the grant project.

Requests for coaching were also on this form.

The final workshop was scheduled for June 2016. During this workshop, all TMI teachers regardless of participation in the study was administered a final DTAMS to fulfill grant requirements. DTAMS scores for study participants were considered the post-test for this study. The post-interviews were conducted during June and July 2016.

The figure below displays the timeline of data collection for this study:

**Figure 3.2. Timeline for data collection**

**Researcher Bias**

As the researcher for this study, it was important to discuss the biases in this study. It was imperative that readers of this study know the personal biases that the researcher possesses. Also, it was important for the researcher to know their own personal biases and reflect on them. When initially hired, the researcher completed an
internship during the first year of teaching. The researcher received a collaborating teacher that provided guidance through that first year and continued the mentorship after the intern year. As a middle and high school mathematics teacher for fifteen years, the researcher served in many roles beyond just a mathematics teacher. The researcher has been a collaborating teacher for both student teachers and interns and a part-time mathematics coach. Also, the researcher regularly attended workshop networks and other professional meetings. These experiences shaped the researcher into someone who saw great potential in working collaboratively with others. Careful consideration was paid to the formulation of interview questions for the protocol as not to be too leading by the researcher’s biases towards workshops and instructional coaching to participants.

Bias can enter a study at many levels. When employing a mixed methods study, ensuring validity of results for both quantitative and qualitative data takes on different methods. Creswell (2014) suggests eight procedures that will enhance qualitative validity and better ensure the accuracy and trustworthiness of the qualitative data. For this study, the researcher employed the following strategies outlined in Creswell’s work: prolonged time in the field, present negative information, and member check.

The collection of qualitative data occurred in Year 3 of the TMI grant. During the previous two years of the grant, the researcher had forged working professional relationships with many of the participants. The researcher had been a visitor in their classrooms to complete classroom observations for the grant. Also, the researcher had fielded emails and phone calls from the participants about the content of the TMI workshops and how to best incorporate it into their classrooms. By the time the researcher started coaching sessions with the participants, there had already been a
professional relationship established that allowed for ease in communication and trust. This led to the researcher being better able to provide instructional strategies and content-related information to the participants congruent to their needs.

When collecting data from the coaching sessions, workshop feedback reflections and interviews (both pre- and post), the researcher made a conscious effort to provide both positive and negative statements about how the sustained professional development that utilized both on-going workshops coupled with coaching impacted both teachers’ content knowledge and perceptions of coaching. Providing participants’ reflections and statements that both supported and refuted the effort of sustained professional development allows for a more critical analysis of what components of the sustained professional development were thought of as beneficial and those that were not seen as beneficial so that a more ideal sustained professional development model could be developed because of this study.

Finally, the researcher used member checks on both the pre- and post-interviews to ensure the accuracy of the transcripts from audio-recorded interviews with the participants. For this study, member checks were conducted by the researcher transcribing the audio-recorded interviews. The transcripts were sent to the participants via email to check for accuracy of the themes and ideas that the participants wanted conveyed on their behalf for this study (see Appendix M). Participants were debriefed on this process during the pre- and post-interview and informed that if there were any inconsistencies in the transcript as it related to their themes or ideas to contact the researcher and the transcript would be edited to reflect the participants’ wishes. During the pre-interview process there were three participants that wanted revisions to their
transcripts. Revisions included withholding some personal information regarding educational background and opinions on school policies. Once participants agreed to the content of their transcripts, they sent an email to the researcher stating that the transcripts could be used for data analysis. The same process was used for the post-interviews. No participants asked for post-interview revisions.

**Analysis of Data**

**Research Question 1: To what extent do middle school mathematics teachers’ content knowledge on proportional reasoning change after on-going math workshops and instructional coaching?**

**DTAMS.** Phase 1 of quantitative data collection assessed the study’s first research question as it related to content knowledge, but it also served as means for the selection of mathematics content interview questions necessary to address the first research question. Descriptive statistics, standard deviations and percent of change from pre- to post scores were calculated for the participants for the whole test and for subdomains Knowledge Types I-IV. Subcategories of statistics included: all participants, gender, years teaching (0-3 years, 4-6 years and more than 6 years of experience), years in the TMI grant (participant throughout or new to grant), number of workshops attended (those attending 4-5 meetings; 6-7 meetings and all 8 meetings) and hours of coaching during the study (2 hours of coaching or more than 2 hours of coaching). Ethnicity and comparison between special education and general education teachers were not included due to small number of minorities and special education teachers involved in this study.

**Semi-structured pre- and post-interview protocols.** The researcher selected five DTAMS questions to administer during both the pre- and post-interviews that were either
indicative of proportional reasoning at the middle school level as dictated by the CCSSM or were examples of topics of upcoming workshops. Those questions were then later expounded upon during the on-going workshops with participants receiving assistance in learning these concepts with activities and direct teaching. To conduct analysis on these five questions, participants’ responses were audio-recorded and transcribed verbatim. Using conventions from Gee (2011b), the initial transcript was divided into lines so that analysis and referencing were made easier. Lines were determined by the following means: changes in speaker, speaker’s mathematical examples or thought-processes, ties to CCSSM, speaker’s misconceptions of a particular problem or narrative stories on how the participant may have instructed students on a particular problem. In post-interviews, evidence of TMI strategies and content were also analyzed. Participant answers were coded based on emerging themes seen across all participants along with correctness. The researcher analyzed the participants’ answers to determine the level of congruence and correctness to the CCSSM along with vocabulary usage and use of multiple representations in their answers.

**TMI classroom observation instrument.** The TMI Classroom Observation instrument used before the start of the study helped to inform the facilitation team of particular mathematical topics that teachers may need help with or instructional strategies that may foster more effective mathematics instruction. It also helped the researcher to determine possible topics for coaching sessions.
Research Question 2: To what extent do middle school mathematics teacher’s perceptions of instructional coaching change after experiencing a coaching relationship?

Semi-structured pre-and post-interview protocol. The use of language in how participants characterized their thoughts and perceptions on PD experiences of on-going workshops and instructional coaching were analyzed extensively in this study. Audio-recorded semi-structured pre- and post-interviews served as the primary data for the second research question. Qualitative analysis included transcribing and coding the semi-structured pre- and post-interviews. First, interviews were transcribed verbatim with natural pauses and utterances noted to preserve the conversational nature of the interview. Upon transcription, those pauses and utterances were not counted in the thematic analysis. Using conventions from Gee (2011b), the initial transcript was divided into lines so that analysis and referencing will be made easier. Lines were determined by the following means: changes in speaker, speaker’s clauses and narrative stories.

According to Gee (2011a), language had seven building tasks which analysis of discourse serves to try to answer. Those tasks included establishing the following: significance, practices (activities), identities, relationships, politics (distribution of social goods), connections and sign systems (knowledge). Grounded theory with thematic analysis was used to analyze the transcripts by examining how participants used language to describe their thoughts and perceptions on instructional coaching. Grounded theory is a “search for themes and patterns to build theory” (Glesne, 2011, p. 186) by using “coding, categorizing, and comparing” (Glesne, 2011, p. 21). Grounded theory techniques used in this study included but are not limited to, convergent (finding common
themes across the participants) and divergent (finding opposing or different themes across the participants) coding.

To organize the transcripts for analysis, Gee’s conventions of “stanzas” were utilized (Gee, 2011b). A stanza was a “group of idea units about one important event, happening, or state of affairs at one time and place or it focused on a specific character, theme, image, topic or perspective” (p. 74). The semi-structured interview protocol allowed stanzas to form because many of the participants’ answers fell in line with the prescriptive nature of the questions. A table was constructed for each transcript with the following headings:

Table 3.2

<table>
<thead>
<tr>
<th>Discourse Analysis Organizer Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transcript</td>
</tr>
</tbody>
</table>

The transcripts for the pre-interview were divided into parts (e.g., Professional Experience/Credentials, Math Courses, Why a Math Teacher, How Students Learn Math, Professional Development, Cohorts for PD purposes, Math focused PD, Instructional Coaching) that corresponded with major topics of the pre-interview protocol. After the transcript was divided into parts, stanzas were created that illustrated a complete thought or narrative the participant gave during the interview. Stanzas were contained within a cell of the table. As a participant changed the focus in his/her answer, a new stanza was created and was typed in a new cell of the table.

Codes were created after all interviews were transcribed and arranged in the table format categorized by parts and stanzas. After the first analysis, it was clear that certain themes were emerging from many of the participants. Those themes were noted on
master list of codes and then each transcript was analyzed again to insert these codes in the appropriate place. A list of the emerging codes can be found in Appendix N. The transcripts were also highlighted and color-coded based on use of language that demonstrated emotion, strong opinions and supported the big D discourse. These emergent themes were checked with current theories on coaching to determine any congruency and tease out discrepancies. Secondary coding was used to find connections among data that was common across participants. The same process of sub-dividing the post-interview transcripts into parts and stanzas and then coding was employed. Themes from the pre-interview served as themes for the post-interviews.

TMI classroom observation instrument. The TMI Classroom Observation Instrument was used to examine the power dynamic of coaching and its translation into the participant’s instructional practices and relationships with students. Data and antidotal records of how participants managed instructional grouping of students, the physical layout of the room, teacher and student-led discourse and integration of TMI strategies were noted before and after the intervention time of workshops and coaching. Changes in classroom practice were noted and the researcher tried to tie any changes to interview data.

Summary of Research Procedures

There were four instruments used to collect data for this explanatory sequential mixed methods study, the DTAMS with a focus in algebraic reasoning and two semi-structured interview protocols. Data were analyzed both qualitatively and quantitatively. The DTAMS assessment served as a quantitative measure of TMI participants’ content knowledge of proportional reasoning. The data were quantitatively analyzed using
descriptive statistics and percent of change. Qualitatively, interview data from both the pre- and post-interviews were audio-recorded and transcribed along with classroom observations before and after the intervention phase. Analysis of interview data included organizing the transcripts into parts and stanzas so that emerging themes were easier to identify both within and among participant data. Emergent themes were given a code and transcripts were coded according to those themes. Color-coding parts of the transcripts was utilized for the thematic analysis of a participant’s emotions and opinions as it relates to big D discourse. Interview data for the five selected DTAMS questions was analyzed both quantitatively and qualitatively. Responses to the mathematics questions were analyzed for correctness along with how well the use of knowledge from the standard (vocabulary and conceptual knowledge) was employed along with use of multiple representations. Data from classroom observations using the TMI Classroom Observation Instrument aided in the planning of both workshops and coaching sessions. It also acted a source of data to demonstrate the change, if any, in classroom practice.
CHAPTER IV
ANALYSIS AND RESULTS

There were two purposes for this explanatory sequential mixed methods study.

First, the purpose was to determine the effect, if any, that instructional coaching, coupled with on-going workshops, had on the participants’ content knowledge of proportional reasoning. Second, this study examined the perceptions that participants held about instructional coaching and its change, if any, on their pedagogy and content knowledge.

To determine the extent to which teacher knowledge changed because of participating in on-going workshops and instructional coaching, the researcher gathered both quantitative and qualitative data (Figure 3.2) There were 14 participants that met the criteria for this study. The following data were collected for all 14 participants: pre- and post-DTAMS scores; pre-interview data and classroom observations before and after the intervention phase of the study. There were two participants that did not participate in the post-interview. Eli in the post-interview answered the questions on coaching but opted to not answer questions over the DTAMS. Karen was not able to participate in the post-interview due to a prolonged family illness. The researcher administered the DTAMS as a pre- and post-test along with audio-recorded interviews with participants answering selected DTAMS questions. Descriptive statistics, standard deviations and percent of change from pre- to post scores were calculated for the participants for the whole test and for subdomains Knowledge Types I-IV, which were:

Knowledge Type I: memorized/factual knowledge
Knowledge Type II: conceptual understanding
Knowledge Type III: reasoning/problem-solving
Knowledge Type IV: pedagogical content knowledge
Subcategories of descriptive statistics included: all participants, gender, years teaching, years in the TMI grant, number of workshops attended and hours of coaching during the study. Ethnicity and comparison between special education and general education teachers were not included due to small number of minorities and special education teachers involved in this study. Transcripts of the participant answers to the DTAMS questions were analyzed for accuracy, mathematical themes and evidence of TMI strategies and content. To determine the extent to which perceptions of coaching changed, the researcher conducted pre- and post-interviews, transcribed the interviews, coded the transcripts and employed grounded theory with thematic analysis.

**Research Question #1**

*To what extent do middle school mathematics teachers’ content knowledge on proportional reasoning change after on-going workshops and instructional coaching?*

The study had 14 participants. Due to the small number of participants, the statistics employed for this study included descriptive statistics: mean, range and standard deviation. Percent of change was also calculated for the means from pre- to post-test. Results for subgroups displayed in the tables below include overall pre- and post-score performance along with Knowledge Types I-IV pre- and post-score performance. Quantitative data for this study included overall participant data along with six sub-categories (gender; years of experience; whether participant was new or returning to the grant project; number of meetings attended during the study and hours of coaching). Overall DTAMS scores had a maximum of 40 points while Knowledge Type I-IV had a maximum of 10 points each.
Overall trends in data. A trend seen in the overall means for the number of points earned from the pre- to post-tests exhibited an increase for every sub-category and sub-group. Additional trends included, the scores for Knowledge Type III exhibited the greatest gains for most sub-groups, while scores for Knowledge Type IV decreased from pre- to post-tests for nearly all the sub-groups. Knowledge Type II also had many sub-groups that decreased from pre- to post-tests.

Overall participant performance on pre- and post-DTAMS. Examination of overall participant data exhibited many of the trends mentioned above. The gain from pre- to post-test means was approximately four points 20.5 (SD 6.25) to 24.1 (SD 5.48), which was a 17.6% change. The greatest percent of change occurred for Knowledge Type III at 34.7% or pre- to post-test means of 4.9 (SD 1.62) to 6.6 (SD 1.18). Data for Knowledge Type IV for overall participants had no change in means from pre- to post-tests. This went against the trend seen in which Knowledge Type IV was a decrease for nearly all the sub-groups. Results for overall participant performance in Table 4.1.

Table 4.1
Descriptive Statistics for All Participants DTAMS Pre-Test and Post-Test

<table>
<thead>
<tr>
<th></th>
<th>Pre-Test</th>
<th>Post-Test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Range</td>
</tr>
<tr>
<td>Overall</td>
<td>20.5 (6.25)</td>
<td>6-30</td>
</tr>
<tr>
<td>Knowledge Type I</td>
<td>5.9 (1.60)</td>
<td>2-8</td>
</tr>
<tr>
<td>Knowledge Type II</td>
<td>6.1 (2.05)</td>
<td>2-9</td>
</tr>
<tr>
<td>Knowledge Type III</td>
<td>4.9 (1.62)</td>
<td>1-7</td>
</tr>
<tr>
<td>Knowledge Type IV</td>
<td>3.6 (1.72)</td>
<td>1-7</td>
</tr>
</tbody>
</table>
**Gender performance on pre- and post DTAMS.** Examination of the performance of females and males on the pre- and post-tests showed some interesting results (Table 4.2). Females’ pre-test mean of 21.3 (SD 4.72) was higher than the males’ pre-test mean of 19.5 (SD 9.31). However, males outperformed the females on the post-test mean 25.3 (SD 8.58) to 23.8 (SD 3.83). The males had a greater percent of change in their mean scores from pre- to post of 29.7% as compared to 11.7% for the females. Females exhibited the trend seen scores increased for all measures except Knowledge Type IV. The female score decreased 15.8% from pre- to post-test in Knowledge Type IV. Conversely, males did not follow the trend by increasing their Knowledge Type IV score by 18.4%. Only two other sub-groups had gains in their Knowledge IV scores. The greatest gain in mean scores for the females occurred with Knowledge Type I at 26.7% with a close second of Knowledge Type III at 24.5%. Males followed the trend of Knowledge Type III exhibiting the greatest gain at 58.1%, which was the greatest gain for any sub-group.

Table 4.2
*Descriptive Statistics for Male and Female Participants DTAMS Pre- and Post-Test*

<table>
<thead>
<tr>
<th></th>
<th>Males</th>
<th></th>
<th>Females</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-Test</td>
<td>Post-Test</td>
<td>Pre-Test</td>
<td>Post-Test</td>
</tr>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Range</td>
<td>Mean (SD)</td>
<td>Range</td>
</tr>
<tr>
<td>Overall</td>
<td>19.5 (9.31)</td>
<td>6-30</td>
<td>25.3 (8.58)</td>
<td>12-36</td>
</tr>
<tr>
<td>Knowledge Type I</td>
<td>5.5 (2.18)</td>
<td>2-8</td>
<td>7.3 (2.59)</td>
<td>3-10</td>
</tr>
<tr>
<td>Knowledge Type II</td>
<td>6.0 (3.08)</td>
<td>2-9</td>
<td>6.8 (2.49)</td>
<td>3-10</td>
</tr>
<tr>
<td>Knowledge Type III</td>
<td>4.3 (2.05)</td>
<td>1-6</td>
<td>6.8 (1.64)</td>
<td>4-8</td>
</tr>
<tr>
<td>Knowledge Type IV</td>
<td>3.8 (2.38)</td>
<td>1-7</td>
<td>4.5 (2.18)</td>
<td>2-8</td>
</tr>
</tbody>
</table>

**Participant performance on pre- and post-DTAMS based on years of teaching experience.** Teachers in the TMI grant had variety in the years of teaching experience.
The following three sub-groups were established for calculating and analyzing statistics: 0-3 years, 4-6 years and more than 6 years of experience (Table 4.3). Growth was seen in all sub-groups for teaching experience. The smallest overall growth was with the 0-3 years participants at 9.9% increase, while the greatest was with the more than 6 years at 25.7%. Those participants in the 4-6 years were close with a 22.2% increase from pre- to post-test scores. Knowledge Type IV was problematic for the more than 6-year sub-group that had no change in scores and with the 0-3 years sub-group that exhibited a 13.5% decrease. Participants in the 4-6 years sub-group recorded an increase of 11.6% in Knowledge Type IV. Participants with 4-6 years of experience had growth of double-digits in all measures. Growth in Knowledge Type III was across all sub-groups. Participants with 0-3 years of experience and more than 6 years of experience had the greatest growth in Knowledge Type III with 25% and 50% respectively. Participants with 4-6 years of experience had similar growth in Knowledge Type I at 33.3% and 32.7% for Knowledge Type III.
Table 4.3
Descriptive Statistics for DTAMS Pre- and Post-Test Based on Participant Years of Teaching Experience

<table>
<thead>
<tr>
<th></th>
<th>0-3 Years Teaching of Experience</th>
<th>4-6 Years Teaching of Experience</th>
<th>More Than 6 Years of Teaching Experience</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-Test</td>
<td>Post-Test</td>
<td>Pre-Test</td>
</tr>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Range</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td>Overall</td>
<td>21.2 (4.88)</td>
<td>16-25</td>
<td>23.3 (3.99)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>9.9</td>
</tr>
<tr>
<td>Knowledge Type I</td>
<td>6.2 (1.21)</td>
<td>4-8</td>
<td>7.3 (1.11)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>17.7</td>
</tr>
<tr>
<td>Knowledge Type II</td>
<td>6.2 (1.86)</td>
<td>4-9</td>
<td>6.3 (1.70)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.6</td>
</tr>
<tr>
<td>Knowledge Type III</td>
<td>5.2 (1.21)</td>
<td>3-6</td>
<td>6.5 (0.96)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>25.0</td>
</tr>
<tr>
<td>Knowledge Type IV</td>
<td>3.7 (1.37)</td>
<td>2-5</td>
<td>3.2 (0.90)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-13.5</td>
</tr>
</tbody>
</table>

Growth (%)

<table>
<thead>
<tr>
<th></th>
<th>0-3 Years Teaching of Experience</th>
<th>4-6 Years Teaching of Experience</th>
<th>More Than 6 Years of Teaching Experience</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Range</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td>Overall</td>
<td>22.5 (4.72)</td>
<td>17-30</td>
<td>27.5 (5.32)</td>
</tr>
<tr>
<td>Knowledge Type I</td>
<td>8.0 (1.41)</td>
<td>4-8</td>
<td>6.0 (1.22)</td>
</tr>
<tr>
<td>Knowledge Type II</td>
<td>6.8 (1.48)</td>
<td>5-9</td>
<td>7.5 (1.66)</td>
</tr>
<tr>
<td>Knowledge Type III</td>
<td>5.5 (7.25)</td>
<td>4-7</td>
<td>7.3 (0.83)</td>
</tr>
<tr>
<td>Knowledge Type IV</td>
<td>4.3 (1.79)</td>
<td>2-7</td>
<td>4.8 (2.38)</td>
</tr>
</tbody>
</table>

Growth (%)

<table>
<thead>
<tr>
<th></th>
<th>0-3 Years Teaching of Experience</th>
<th>4-6 Years Teaching of Experience</th>
<th>More Than 6 Years of Teaching Experience</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>9.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knowledge Type I</td>
<td>17.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knowledge Type II</td>
<td>1.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knowledge Type III</td>
<td>25.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knowledge Type IV</td>
<td>-13.5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Participant performance on pre- and post DTAMS based on TMI participation.**

This study was conducted in Year 3 of the TMI grant. Some participants left during the grant due to a change in teaching assignments or retirement. Therefore, some teachers were new to the grant when they agreed to participate in this study. Participants who had been a part of the grant for the previous two years were compared to those participants who were new to the TMI grant (Table 4.4). Both sub-groups exhibited similar growth for the overall pre- to post-test means. Those new to the grant increased their mean score from 18.7 (SD 5.44) to 21.7 (SD 4.19) or 16.0% change, while participants throughout the grant increased from 21.0 (SD 6.37) to 24.8 (SD 5.59) or 18.1% change. Both sub-groups showed growth in all measures except Knowledge Type IV. Those participants throughout the grant had mean scores that decreased by 2.6%, while those new to the grant had no change in their mean scores from pre- to post-test. The greatest growth occurred with Knowledge Type III for those participants throughout the grant at 31.4% while new participants were at 39.5%. New participants had a 5% decrease in Knowledge Type II of 5%, while no other sub-group had a decrease in Knowledge Type II.

**Table 4.4**

*Descriptive Statistics for Participants Membership in TMI DTAMS Pre- and Post-Test*

<table>
<thead>
<tr>
<th></th>
<th>Participants Throughout TMI</th>
<th>Participants New to TMI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-Test</td>
<td>Post-Test</td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>Range</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td>Overall</td>
<td>21.0 (6.37)</td>
<td>6-30</td>
</tr>
<tr>
<td>Knowledge Type I</td>
<td>6.0 (1.71)</td>
<td>2-8</td>
</tr>
<tr>
<td>Knowledge Type II</td>
<td>6.1 (2.02)</td>
<td>2-9</td>
</tr>
<tr>
<td>Knowledge Type III</td>
<td>5.1 (1.68)</td>
<td>1-7</td>
</tr>
<tr>
<td>Knowledge Type IV</td>
<td>3.8 (1.75)</td>
<td>1-7</td>
</tr>
</tbody>
</table>
**Participant performance on pre- and post-DTAMS based on number of TMI workshops attended during the study.** There were eight six-hour workshops conducted during the duration of this study from July 2015 to March 2016. Although attendance was highly recommended by both school districts and the TMI facilitators, some participants did not attend all workshops. Reasons included sickness, conflicts with school events and vacations scheduled during the summer workshops. Participants were divided into three sub-groups based on their attendance: those attending 4-5 meetings; 6-7 meetings and all 8 meetings (Table 4.5).

All three sub-groups showed increases in their overall mean scores. The greatest percent of change in overall scores was 22.9% for those attending 4-5 meetings followed by 19.6% for those attending all 8 meetings and 7.3% for those attending 6-7 meetings. Gains were seen for many measures for these sub-groups. Those attending 4-5 meetings had the greatest gain in Knowledge Type III at 57.9% along with a gain of 40% on Knowledge Type I. Those participants that attended 6-7 meetings had gains in all measures except Knowledge Type IV, which was in keeping with the overall trends seen. The greatest gain was 22.2% in Knowledge Type II with only a 5% increase in Knowledge Type III. Those participants attending all 8 workshops had gains in all measures. Their overall greatest gains were in Knowledge Type III with 32.1% with a similar gain of 30% in Knowledge Type I.
Table 4.5
Descriptive Statistics for DTAMS Pre- and Post-Test Based on Number of TMI Workshops Attended

<table>
<thead>
<tr>
<th></th>
<th>4-5 Workshops Attended</th>
<th>6-7 Workshops Attended</th>
<th>All 8 Workshops Attended</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-Test</td>
<td>Post-Test</td>
<td>Pre-Test</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>(SD)</td>
<td>Mean</td>
</tr>
<tr>
<td>Overall</td>
<td>17.5</td>
<td>(7.54)</td>
<td>21.5</td>
</tr>
<tr>
<td></td>
<td>6-28</td>
<td></td>
<td>12-28</td>
</tr>
<tr>
<td>Knowledge Type I</td>
<td>5.0</td>
<td>(1.63)</td>
<td>7.0</td>
</tr>
<tr>
<td></td>
<td>2-7</td>
<td></td>
<td>3-9</td>
</tr>
<tr>
<td>Knowledge Type II</td>
<td>5.7</td>
<td>(2.56)</td>
<td>5.5</td>
</tr>
<tr>
<td></td>
<td>2-9</td>
<td></td>
<td>3-7</td>
</tr>
<tr>
<td>Knowledge Type III</td>
<td>3.8</td>
<td>(1.77)</td>
<td>6.0</td>
</tr>
<tr>
<td></td>
<td>1-6</td>
<td></td>
<td>4-8</td>
</tr>
<tr>
<td>Knowledge Type IV</td>
<td>3.0</td>
<td>(1.83)</td>
<td>3.0</td>
</tr>
<tr>
<td></td>
<td>1-6</td>
<td></td>
<td>2-4</td>
</tr>
</tbody>
</table>

Growth (%) calculated as Post-Test Mean - Pre-Test Mean / Pre-Test Mean * 100

Mean Growth (SD) for Overall: 23.3 (0.82) 4-5 Workshops, 24.0 (0.82) 6-7 Workshops, 23.3 (0.82) All 8 Workshops
Participant performance on pre- and post DTAMS based on number of coaching hours received during the study. Participants had access to coaching as an added support to assist in the implementation of learning from TMI workshops. The TMI grant stipulated that each participant would have two observations with two, one-hour coaching sessions. Participants contacted the researcher and developed a coaching plan tailored to their needs. Coaching occurred in the form of face-to-face coaching sessions, emails, phone calls, co-teaching and curriculum development. Participants were divided into two groups based on the coaching hours received: those receiving the base two hours of coaching and those that received more than two hours of coaching (Table 4.6).

Regardless of the amount of coaching, both sub-groups overall scores grew. Those with 2 hours of coaching went from 18.8 (SD 8.23) to 22.3 (SD 7.70) for a 18.6% increase in means while those receiving more than 2 hours of coaching went from 21.8 (SD 3.73) to 25.5 (SD 1.94) for a 17.0% increase in means. Knowledge Type IV was problematic for both sub-groups. Those that received 2 hours of coaching had no change, while those that received more than 2 hours of coaching decreased by 2.8%. Those with 2 hours of coaching also had a decrease of 1.7% in Knowledge Type II. In keeping with the overall trends, Knowledge Type III was the measure in which each sub-group had the greatest gains. For those that received 2 hours of coaching, their scores went from 4.2 (SD 1.95) to 6.0 (SD 1.29) for a 42.9% increase, while those that received more than 2 hours of coaching went from 5.5 (SD 1.00) to 7 (SD 0.87) for a 27.3% increase in means.
Table 4.6.  
*Descriptive Statistics DTAMS Pre- and Post-Test Based on Participants Hours of Coaching*

<table>
<thead>
<tr>
<th></th>
<th>2 Hours of Coaching</th>
<th>More Than Two Hours of Coaching</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-Test</td>
<td>Post-Test</td>
</tr>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td></td>
<td>Range</td>
<td>Range</td>
</tr>
<tr>
<td></td>
<td>Overall</td>
<td>18.8 (8.23)</td>
</tr>
<tr>
<td>Knowledge Type I</td>
<td>5.2 (1.86)</td>
<td>7.0 (2.38)</td>
</tr>
<tr>
<td>Knowledge Type II</td>
<td>5.8 (2.54)</td>
<td>5.7 (2.36)</td>
</tr>
<tr>
<td>Knowledge Type III</td>
<td>4.2 (1.95)</td>
<td>6.0 (1.29)</td>
</tr>
<tr>
<td>Knowledge Type IV</td>
<td>3.7 (2.13)</td>
<td>3.7 (2.05)</td>
</tr>
</tbody>
</table>
TMI Training and Its Effects on DTAMS

The quantitative data trends seen in DTAMS Knowledge Types exemplified the types of training that were provided in the workshops and coaching sessions. Knowledge Type III was categorized as:

The mathematics knowledge is higher order in nature. It includes applying knowledge to solve problems and real-world applications. Teachers with this knowledge can reason informally and formally, conjecture, validate, analyze and justify. They can use deductive, inductive, proportional, and spatial reasoning to solve problems. (http://louisville.edu/education/centers/crimsted/diag-math-assess-middle).

The study included intensive focus on proportional reasoning. Workshops challenged participants to look at proportional reasoning as more than just cross-products. Hands-on activities and labs that gathered real-world data were studied in six of the eight workshops. Results were analyzed in multiple representations to extrapolate values. Participants also examined visual patterns that increased or decreased of dots on paper and multi-link cubes to determine proportionality, slope and y-intercept. This work in spatial reasoning coupled with proportional reasoning could have been one of the reasons why Knowledge Type III saw the greatest increase among all sub-groups.

Unfortunately, the work of TMI in this study did not have the same increasing effect on Knowledge Type II and IV. Knowledge Type II was characterized as: “…deep understanding of mathematical concepts, procedures, laws, principles, and rules. It is the knowledge of connections and relationships among concepts…give examples/non-examples…represent mathematical concepts and generalizations in multiple ways…represent them in multiple ways.” (http://louisville.edu/education/centers/crimsted/diag-math-assess-middle). While Knowledge Type IV was characterized as: “… knowledge unique to teaching
mathematics … knowledge of the most regularly taught topics in mathematics, the most useful forms of representations of those ideas … Teachers with this knowledge can identify student misconceptions about mathematics and provide strategies to correct them…” (http://louisville.edu/education/centers/crimsted/diag-math-assess-middle).

Participant performance in these two Knowledge Types was disappointing. The eight workshops dealt with understanding the conceptual underpinnings of proportionality and how it manifested itself in multiple representations. There were a variety of instructional strategies and technologies (See Appendices Q and R) taught during workshops that participants were encouraged to use with their students. Time for participants to share how strategies were implemented and the results during each workshop. However, facilitators perhaps provided too many strategies and not enough time for participants to understand the purpose and which misconceptions the strategies addressed. In other words, there was a “strategy-overload” in which participants were provided several strategies, but the true instructional intention for each strategy was not realized by the participants. Also, there were only five out of fourteen participants that attended all eight workshops (48 hours), while six only attended four or five (24-30 hours) workshops. Yoon et al., (2007) reported that professional development lasting fourteen or fewer hours showed no effect on student or teacher learning, whereas programs offering more than fourteen hours of sustained, content-focused professional learning showed significant positive effects. Professional learning opportunities that worked with teachers between 30 and 100 hours over a minimum of six to twelve months had the greatest effects. If participants had attended all the workshops, then they would
have above the minimal number of hours that research has shown changes teacher learning.

Garet et al., (2001) noted five characteristics of highly effective professional development included: content focus, active learning, coherence, collective participation and duration. The workshop experience in this study established by the TMI grant did fit three of these characteristics. The workshops did have an established content focus on proportional reasoning that examined proportionality and how to teach it to students along with common misconceptions. There was collective participation in that teachers worked together as a cohort from a variety of grade levels and schools. The study’s duration of eight workshops focused on proportionality instead of only meeting once.

However, two important characteristics were not met in the study, which may have contributed to the lower post-scores in Knowledge Types II and IV were active learning and coherence. Active learning was characterized as teachers discussing content, examining student work and participating in hands-on activities (Garet et al., 2001). Examining TMI’s agendas for this study, it was not clear the amount of time allotted for active learning. Although all participants expressed value on working with others at different grade levels and schools in post-interviews, the TMI facilitators did not take full advantage of the community of practice established through this grant. Participants chose to either incorporate or not incorporate strategies. Therefore, some participants possibly never shared or even tried to incorporate strategies or new learning in their classroom. Participants that incorporated any strategy from a workshop were encouraged to share their experience, but there was no set time for reflection or protocol for participants to share or reflect on incorporating strategies in the classroom.
Additionally, not all participants attended all meetings. Therefore, the lack of *active learning* with a spotty attendance record could have led some participants to not take full advantage of the learning the workshops provided. Knowledge Type II and IV hinged on the participants’ knowledge of mathematics and how to teach it. If participants did not attempt strategies introduced in the workshops or regularly attend the workshops, then it stood to reason that learning that supported Knowledge Type II and IV would not increase.

Another characteristic of high quality PD not fully developed in the study was *coherence*. *Coherence* dealt with the information introduced in the workshop was consistent with both teacher beliefs and content knowledge along with school/district expectations (Garet et al., 2001). As stated earlier with *active learning*, the TMI facilitation team did not set aside adequate time for participants to reflect on their learning and how it related to their own belief system. Stella noted in her post-interview: “Then you try it and then we reflect on it...we should have had this 30-minutes to one hour. I know that’s not possible but it was needed. Now take out your laptop, look at your maps and your everything and try to fit it into your curriculum”. Other participants noted in their post-interviews that they wished there had been more time to reflect on strategies and learning from meetings so that it could be better incorporated in their classroom practice. Not providing time for participants to reflect and determine where strategies and learnings needed to be incorporated in their curriculum possibly led to Knowledge Type II and IV not increasing in every sub-group. Additionally, there were six of the fourteen participants that were teachers in a district that used the gradual release model of “I do, We do, You do” model of classroom instruction (Grant, Lapp,
TMI strategies hinged on conceptual understanding, multiple representations and data collection activities. Three of the six participants from this district noted that sometimes they did not feel comfortable incorporating some of the TMI strategies because the strategies went against district policy. Therefore, Knowledge Type II and IV that characterized teachers needed conceptual knowledge and ability to compare and contrast mathematical concepts and multiple representations possibly were not addressed in these six classrooms. Conversely, the gradual release model suggested that a teacher was to model how to solve a problem (possibly using an algorithmic approach). After a few examples by the teacher, the students were to practice similar problems with the approach modeled by the teacher. After the student-work was checked in class, then students were to continue work on similar problems (Grant et al., 2012). Participants that adhered to their district policy were not likely to incorporate TMI strategies that exemplified Knowledge Type II and IV, thus the post-test scores did not increase for every sub-group as desired.

**Participant Demographics for Those with Highest Post Scores or Greatest Gain from Pre- to Post**

Upon examination of the participants’ DTAMS scores, trends were seen in participants’ demographics. Participants were rank ordered based on their post-test scores and then again on the gains made from the pre- to post-test.

Examination of the highest post-test scores saw many participants tied for fifth place. Therefore, the top four participants were examined. The study found that three of the four participants had more than the required two hours of coaching as stipulated by the TMI grant. Also, three out of the four attended all eight of the meetings. Finally, all
four participants had been a part of TMI for the duration of the grant. Although causation was not assigned, it seemed that the more time participants had with professional learning whether that was in workshops or coaching yielded higher post-test scores.

Examination of participants who had the greatest gains from pre- to post-test was not as clear-cut. Six participants had gains of three points or more from pre- to post-test. The study found that three participants had the minimal amount of coaching required by the grant, whereas the other three participants had more than the required amount of coaching. Three participants attended 4-5 workshops, whereas three participants attended all workshops. Finally, five of the six participants had been a part of TMI for the duration of the grant. It seemed that for this set of participants, membership in the TMI grant for multiple years could have helped participants to have higher gains from pre- to post tests.

Statistics supported that there was a general overall increase of participant pre- to post-test score means and overall scores. Unfortunately, the separate effect that workshops and coaching had on the increase of from pre- to post-test scores cannot be determined with the data collected in this study.

**Qualitative Interview Questions from DTAMS.** To further examine the change in both content and pedagogical knowledge, the researcher asked participants to solve math questions from the DTAMS in both the pre- and post-interviews. Quantitative data provided a lens through which to see if there had been any numeric change in participant knowledge from pre- to post-test. However, the researcher wanted to collect data that went beyond numbers and examined the depth to which their content and pedagogical knowledge had changed. Themes in participant responses included: vocabulary usage,
ability to justify an answer in multiple representations along with TMI strategies discussed. These themes were examined to determine the level to which participant content and pedagogical knowledge had changed.

The researcher selected five DTAMS questions to further study the change in participant mathematical content knowledge to administer during both the pre- and post-interviews. These five questions were chosen prior to the study based on content that was to be highlighted during the workshops. After the study was completed, it was noted that only three of five questions aligned with the actual content of the eight TMI workshops, therefore those three questions were used for analysis in this study. Due to copyright restrictions, those questions were not shared in this paper, however a synopsis of the content tested on each item was included:

Question #1: Question on Linear Functions in Table--This question asked participants to identify the table that was not a linear function. Distractors included tables that had negative values, tables with constant rates of change, a table that had all y-values equal and a table that had y-values that doubled.

Question #2: Question on Real World Meaning of Rate of Change (Slope) and Y-Intercept--This question provided a real-world scenario in which an item had an initial cost and additional cost based on per months or quantities. Participants wrote an equation for the real-world task and then used the function by substituting in a quantity to determine the amount of money spent. Participants were asked if the real-world scenario was proportional.

Question #3: Question on Teaching Slope--Participants responded to a scenario in which a teacher had students struggling with the concept of slope and finding points on a line. Participants were to describe an activity or activities that would help students to understand these concepts.

For the pre-interview, all fourteen participants agreed to answer the mathematics questions. The post-interview had twelve participants respond. One participant did not
agree to answer the mathematics questions, while another participant did not participate in the post-interview due to a prolonged family illness.

Analysis of participant answers from the interview questions revealed three major themes: participants used multiple representations more often in post-interviews than pre-interviews to explain their reasoning; increased math specific vocabulary usage from pre- to post interviews; and articulated using instructional strategies that fostered community of practice in their own classrooms.

**Multiple representations.** A theme most prevalent among participants and across questions was multiple representations, which was reflective of the TMI work. One TMI grant goal was to “Enhance 6-9 teachers’ conceptual understanding and pedagogical content knowledge need to effectively design instructional experience for math concepts” (TMI Grant). The TMI facilitation team determined that to meet this goal, participants studied multiple representations, meaning a mathematical task or situation represented as a table, graph and equation (NGACBP & CCSSO, 2010). This plan matched one of the grant’s student outcome goals in which students were to exhibit understanding and application of multiple representations (TMI Grant). Each of the eight TMI workshops during this study focused on multiple representations. The pre-interview responses hinged mainly on participants using one representation to explain their reasoning. This one-dimensional approach was widened in the post-interview with participants using more representations to explain their reasoning.

For Question 1 in the pre-interview, many participants plotted the points from each table to test if the points did make a line. Stella, Mark, Ellen, Rose, Derek and Marie all exhibited this method of justifying their solution in the pre-interview. Marie
noted that she teaches her students “mapping out” the points or plotting. All participants mentioned above either physically plotted the points on paper with a pencil, on the table/in the air with their fingers in the pre-interview. Responses were very one-dimensional in that plotting points to graph each table to determine linearity and justify their reasoning was the representation used exclusively by most participants.

Three participants in the post-interview primarily used the visualizing/physically plotting points to justify their answers. Rose predominately used this method in her justification, yet chose the incorrect answer. She noted that Distractor D was a horizontal line, yet still chose that distractor as her answer. The other two participants who continued to use the visually/physically plotting points strategy were Derek and Marie. Derek who used this strategy exclusively in his pre-interview and Marie who “mapped out” originally, both had correct answers in the pre-interview. However, in the post-interview each deviated between visualizing and quantifying numeric patterns in the post-interview and chose the incorrect answer in the post-interview. Derek opted for the Distractor D that was the horizontal line because he quantified the rate of change as zero. He noted that zero means it had no rate of change, therefore it is not a constant rate of change, it is not a line. Derek was not alone in this misconception. Jason and Samantha both used the same thinking to justify their answers during the pre-interview, while Rose and Stella did the same in the post-interview. Distractor A in the pre-interview and D in the post-interview had repeating y-values. For all those that correctly answered this question, all used the method of plotting points or visualizing the table as a horizontal line to justify their reasoning.
Numerically speaking, all participants in the post-interview attempted to calculate the rate of change for at least one of the tables. Six participants in the post-interview calculated the rate of change for each table, which all led to correct responses. There were some misconceptions through the interviews. Some participants exhibited uneasiness with negative values. Ellen in the pre-test noted that she chose a distractor because “it looked different with negative values.” Rose noted in her post-interview that a distractor was non-linear because it “had negative values.” Stella noted in her pre-interview that she wanted to “skip” the negatives and just focus on the positive values. There also was an issue with calculating the rate of change with Samantha. She calculated one table to have a rate of change of 1/12, yet it should have been 12. Samantha had inadvertently switched the formula from change in $y$ over change in $x$ to change in $x$ over change in $y$. Samantha was the only participant that verbalized this misconception. Also in the post-interview, decimal values for $y$ perplexed many of the participants. Often, they requested a calculator to ensure that the decimals were increasing by the same amount throughout the table. Marie noticed in Distractor B that the first three entries increased by 0.75 on the $y$-values. When calculating the change from 2.75 to 3.5, she miscalculated. Due to this miscalculation, Marie incorrectly chose B as non-linear. Marie verbalized that a linear function had a constant rate of change, yet a calculation error caused her to miss this question. Ellen and Stella calculated fractions for each point, using $y$ over $x$. They noted that if all the fractions were reduced to equivalent fractions, then the table was linear. Although participants used different terminology for these methods of quantifying the rate of change, the idea behind them hinged on the proportion of increase or decrease among points. An unfortunate trend
seen this question along with Question 2 was that many participants believed both during the pre- and post-interviews that linearity was synonymous with proportionality. Those that exhibited this idea used the reasoning that if the table was going up by the same amount, then it was proportional. They did not consider that the y-intercept must be zero for a proportional relationship.

The wording of Question #2 asked participants to derive an equation for the real-world scenario, which led all of them to provide equations. In the pre-interview, twelve out of fourteen could write correctly an equation for the situation. Participants were the most successful on this question in the both the pre- and post-interview. All participants on the pre-interview except for Rose and Eli correctly wrote an equation, defined the meaning of each variable and used the equation by substituting in a value for x to find the total cost. Rose switched the rate of change with her y-intercept, thus multiplying the variable by the wrong quantity. Eli did not provide an answer during the pre-interview, noting that the question was “nothing they hit in sixth grade.” However, Stella who taught sixth grade in the same district noted, “I would give this to my students. This is realistic”. Eli was a special education collaborating teacher, while Stella was a regular education teacher. Perhaps the difference in teaching assignments colored their judgement on the appropriateness of the question. Nonetheless, Sixth Grade Math Common Core Standards (NGACBP & CCSSO, 2010) had students create and extend ratio tables and write subsequent equations. Although the Standard noted the equations are in the form $y=lx$ and this problem had an equation in the form $y=mx+b$, the numeric patterning and equation writing have been in the sixth-grade standards.
When asked about whether this question was proportional, participants struggled on both the pre- and post-interview. Eleven out of thirteen participants on the pre-interview incorrectly stated that the scenario was proportional. The common misconception that participants voiced was a constant rate of change meant that the scenario was proportional. Jason’s stance, “it was increasing by the same amount, therefore it’s proportional” summarized what the other participants who were incorrect verbalized. Although this stance was true, it meant that the scenario was linear, but not necessarily proportional. All these participants thought that linearity was synonymous with proportionality, which was a common misconception. Mark and Linda were the only two who correctly identified this problem as non-proportional in the pre-interview. Linda noted that it was non-proportional because the graph did not go through the point (0, 0), while Mark said, “proportional or direct variation has to intersect the origin.” Both used the graphical representation to justify their answer, although neither noted a constant rate of change as an additional requirement for proportionality.

Results from the post-interview moved more in positive direction, although still lacking. Each participant provided the correct equation, defined the meaning of each variable and correctly substituted a given value to find the total cost. Five out of the twelve participants still incorrectly answered that the scenario was proportional. As in the pre-interview, participants noted that the scenario’s constant rate of change was the sole reason why it was proportional. Samantha tried to explain in terms of the scenario: “whether it’s for one month or two months, it is going up by the same…so it’s proportional.” The other participants who incorrectly identified this scenario as proportional verbalized the same reasoning.
Seven out of the twelve participants correctly answered this question on the post-test. Participants used multiple representations to defend their stance that this scenario was non-proportional. Graphically speaking, the participants that were correct all noted the graph had to go through the origin, yet there was another reason given in the post-interview. All participants talked about how the “initial cost” or “flat fee”, made the scenario have a $y$-intercept added onto the rate of change in the equation, which would mean the graph did not go through the origin.

The other five participants held a common misconception that proportionality and linearity were the same. Jason was moving in the right direction, but had a flaw in his reasoning. He noted it was proportional because it had a $y$-intercept, although by definition, proportional relationships have a $y$-intercept of zero (Lobato, Ellis, Zbiek, 2010). Participants still holding this misconception on proportionality was disappointing because multiple representations in proportionality were explored in all eight workshops in this study.

However, a positive trend seen in some participant post-interview answers demonstrated they truly understood proportionality. Three participants went further in their answers and noted how to make this scenario proportional. Stella and Marie both noted that the initial cost split among monthly payments made the scenario proportional. A flaw in this idea was that this initial cost would have to be equally distributed among many months not quantified. Sasha offered another solution. She noted to just drop the one-time fee and only pay the monthly installments, which created a proportional relationship. Sasha nicely summed up this scenario when she said, “it is not proportional,
but it is linear.” She understood the hallmark of this problem and the standard for which it was written.

Participant answers on Question #3 from pre- to post-interviews varied in the complexity of pedagogy and the number of representations used to teach slope. In the pre-interview many participants simply stated, the definition of slope and said students needed real-world examples with some activities to “see” slope. Yet in the post-interviews, participants provided more instructional strategies and conversation on multiple representations.

A common phrase used by seven of the fourteen participants in the pre-interview was “rise over run.” Participants noted students needed to understand this idea to understand slope. Derek noted activities were important to student learning when he said “You can see it. You can see it happening. It might help them a lot.” Describing activities was a major theme in the pre-interview. Derek noted students using clinometers might help in understanding how slope is derived and its definition. He had just purchased a classroom set and was looking forward to using them in class. Ellen noted an activity she did as a high school student in which they applied the Americans with Disabilities Act to determine if ramps on campus met the law’s specification. She has never tried this activity with her students, but thought it might be fun. Rose stated she took her students to Gatti-Land for a math field trip in which they counted the number of times they crashed their bumper cars in a minute, then they had to figure out how many times they would crash in a five-minute period. Lizzie noted she used real-world scenarios on the slant of skyscrapers and tilt of a wheel chair ramp from her Digits curriculum. Ten of the fourteen participants echoed the sentiment of providing real-
world scenarios in the pre-interview. However, Madelyn provided an additional consideration to providing real-world scenarios. She noted that a previous interview question dealt with the number of CDs a child bought. Madelyn noted that buying CDs was an outdated idea for children and perhaps downloading songs would be more appropriate. She continued that real-world meant contexts students can make sense of and interact with in class. In each pre-interview described above, the participants discussed activities that seemed to have student engagement and demonstrated what slope looked like. However, discussions lacked how to instruct students on connecting multiple representations and most importantly, how these activities supported the idea of slope. It seemed to the researcher, these were engaging activities for entertainment purposes rather than for instruction.

Cara and Karen’s answers from the pre-interview demonstrated they each used multiple representations in their instruction. Cara noted she had students work with graphs, equations and tables to better understand slope. Karen noted she used slope and rate of change interchangeably in her instruction to prepare her eighth-grade students for the idea of non-linear in high school. Karen gave a rich example of how she taught slope by posing a task such as: Mountain Dew is $3 a carton. How much is your grocery bill increasing as you buy more Mountain Dew? How much would two or three cartons cost? From this scenario, Karen helped her students to work through tables, graphs and equations to see how slope looked in each representation. She tied this idea back to unit rate. Karen was not the only one to talk about unit rate, Madelyn in her post-interview discussed how slope and unit rate are one in the same. Karen eloquently stated:

I mean the main thing going from the different views of a graph to a table to an advertisement or picture and looking at those multiple representations, but you
know to me, that’s where I would try to help students to connect with something they understand.

In her pre-interview, Karen already exhibited the mindset TMI wanted for its participants. It would be interesting to examine the growth, if any, Karen had, but unfortunately, she was unable to complete the post-interview due to a prolonged family illness. However, her sentiments from the pre-interview were more in keeping with the responses that participants provided in the post-interviews.

Although the topic of proportionality was a focus of the TMI workshops for this study, real-world scenarios and hands-on labs were planned for three of the eight workshops. During these workshops, activities from Kentucky Education Television’s Scale City and hands-on labs such as Penny Bridges, Spaghetti Bridges, All Knotted Up, Inches-Centimeters What’s the Difference, How Many Noses are in Your Arm and the Cleaning Power of Borax were used to collect data, create tables and graphs. An instructional strategy, known as NAGS Link sheet (See Appendix S) allowed for participants to create multiple representations of their data and determine if a set of data was proportional or non-proportional. Use of DESMOS as a graphing utility aided participants in graphing their data. Although causation cannot be established in this study, through workshop evaluations, it was noted by participants that these activities did positively impact their understanding of proportionality, which may have increased the number of participants who answered this question correctly from the pre- to post-interview.

One coaching session individually each with Stella, Sasha, Karen and Lizzie, provided more insight to proportional relationships. The content for each of these sessions was the same. The researcher provided more written real-world scenarios along
the with NAGS Link sheet (Appendix S) for the participants to practice before using in the classroom. The researcher also co-taught lessons with Sasha on this topic. Students were engaged in the tasks and noted that the NAGS Link sheet was helpful in having all the multiple representations in front of them to discuss with peers in class. Lizzie was so happy with this strategy that Lizzie’s principal requested the researcher provide PD for the rest of the middle school mathematics department later. Karen took this strategy and taught it to other eighth grade mathematics teachers in her building. This strategy is now a part of each teacher’s unit on functions. Stella was the one who made the connection of “constant of proportionality” and “slope/rate of change”. She noted that her understanding of mathematics had just increased because of this work. Each participant who was coached on this topic had a positive experience and noted their content knowledge had increased and they had a new strategy to expand their pedagogy.

Out of the twelve participant responses from the post-interview, all twelve had elements of multiple representations in their answers. The post-interview responses also had more examples of the instructional practices highlighted in TMI. Four participants highlighted manipulatives as an instructional strategy, which would help to support the student learning. Both Linda and Madelyn noted they would use pegboards to help students to see how slope increases or decreases and reiterate the idea that graphically slope is a series of similar triangles. Linda, Mark and Cara also noted they wanted students to use multi-link cubes or tiles to build patterns and examine the rate of change, then use the NAGS Link sheet to examine slope in multiple representations by graphing, creating a table, deriving an equation and then writing about how rate of change and y-
intercept are seen in the visual pattern. This idea was in keeping with the concrete, representational, abstract (CRA) activities participants experienced in TMI.

Technology integration was in four participant’s answers. Jason, Stella and Ellen noted they used DESMOS, an on-line graphing calculator, to show the connections between graphs and tables to their students. Each also said they would use DESMOS as a tool for students to construct multiple representations from data-collection activities. TMI facilitators demonstrated DESMOS during workshops and participants were encouraged to use it in data collection activities. Ellen, a special education collaborator, said technology was a tool that helped her students so much and leveled the playing field with regular education students. Cara added an interesting spin with using an Apple watch to collect data like steps walked or speed ran.

The three participants that exhibited the greatest amount of growth in pedagogy were Jason, Marie and Sasha. In the pre-interview, Jason provided examples of how to illustrate slope. He talked of ski slopes to show positive and negative slopes, which he said he stole from Dan Meyer. Jason also noted he used the idea of roller coasters to illustrate positive and negative slopes. Throughout this conversation on this question in his pre-interview, Jason provided examples of how he would help students to see slope, but no conversation about how to help students truly understand how slope manifests itself. Jason’s answer centered on DESMOS-integration in his post-interview. He noted DESMOS had sliders that could help students to better understand and make connections of how slope looked graphically and numerically (in equations). Jason pointed out DESMOS was a multiple representation manufacturer with its ability to graph, create tables and derive equations. Jason’s growth was one in which he moved from a teacher
that demonstrated mathematics to one who pushed students to make connections in how slope was seen in multiple ways.

Marie had pedagogical growth from pre- to post-interview as well. During the pre-interview, Marie said she liked to help the students to work the “math portion” first in slope before she applied the real-world scenario. The “math portion” Marie discussed was the slope formula. Marie said, “Once we feel comfortable with the math, then we add in more real-world”. This thought was in direct conflict with the TMI grant in which real-world contexts and scenarios provided more opportunities for student learning from the onset. In her post-interview, Marie’s beliefs were the opposite. Marie said she believed students should have data collection labs and real-world scenarios so that multiple representations had more meaning.

Sasha also had a tremendous amount of pedagogical growth from pre- to post-interview. In the pre-interview, she said that slope is “a proportion of y to x”. Sasha said she wanted students to know slope was everywhere but did not elaborate on how she taught slope. In the post-interview, Sasha provided a few examples of how she would teach slope. First, she explained she would provide a task in which students would work individually to construct a different representation of slope. Then students would participate in a “table top” strategy of combining their various representations to make connections of how slope was seen across the representations and any patterns they noticed. Sasha also shared about an activity she developed in which there was a race between a rabbit and a snail. The snail had a 3-minute head start. The snail moved at a rate of 2 feet per minute while the rabbit moved at a rate of 3 feet per minute. Sasha said she had the students first act out the scenario and then created the graph, table and
equation for this scenario. Sasha’s growth from pre- to post-interview was in the number of instructional strategies she described. Previously, Sasha had difficulty in finding slope around her. Through workshop participation and the researcher co-teaching and consulting with Sasha through email, she had great command of strategies for students to experience the meaning of slope and how it tied to the multiple representations.

Sasha’s idea of having students act out a scenario were nothing new. Three participants discussed how students acted out graphing slope by becoming human coordinate points on a coordinate plane made on the floor of their classroom. Cara noted it in her pre-interview, while Mark noted it in his post-interview. Madelyn spoke of this strategy in both interviews. Her views on math instruction were to provide as much concrete instruction as possible. Madelyn said, “…if they are not understanding the actual equation and looking at the graphs, maybe they physically need to get up and move around, actually physically practice what they are doing.”

Madelyn’s sentiment was one of the beliefs of TMI. Multiple representations were a topic that some participants voiced a concern over both in person and on workshop evaluations. Facilitators worked to provide instructional strategies, labs and websites to expand the participants’ pedagogy and resources. As stated earlier, facilitators conducted numerous labs so participants could gather data and learn how to create multiple representations.

**Vocabulary usage.** Research indicates effective teachers have command of content-specific vocabulary (Barton & Heidema, 2002). Responses to all three questions in the interviews demonstrated the positive change in vocabulary usage participants used to justify their reasoning. The wording in Question 3 specifically used “slope”.
Participants did use “slope” in their responses not only in Question 3 but in all the questions. The term, “constant rate of change” was prevalent as well with six participants in the pre-interview and eight in the post-interview used this term. A trend seen in the post-interview was that participants were using a vertical progression of vocabulary terms to justify their reasoning. Participants at various grade-levels were grouped to work on a variety of tasks during TMI workshops. These groupings were changed throughout the workshops, so participants could work with a variety of others. A community of practice was set up that aided participants in making connections to vocabulary across grade levels.

Grade-level terminology was prevalent in the participants’ answers. Seven of the participants, who also were sixth grade teachers, used various terms like “scale”, “same ratio”, “equal increase or decrease”, “reduced fraction” and “scale factor” in their justifications. Terminology like this was logical since the CCSSM has scale factors and ratios for sixth grade (NGACBP & CCSSO, 2010). The five participants who taught eighth grade used terminology like “slope”, “(constant) rate of change” or “slope as a ratio”, which is found in the eighth grade CCSSM (NGACBP & CCSSO, 2010), to justify their reasoning. Since participants had a good command of grade-level vocabulary, it aided in vertical grade-level conversations that occurred during workshops and coaching sessions. Cara noted her vocabulary increased after working with other participants that taught a different grade she did. She noted,

And some of the vocabulary that some of the teachers were using...at the session...well that is probably how I need to call it if that is how they are going to call it that in middle school. Even our books use different vocabulary than the vocabulary that they are going to use in 7th and 8th grade. I was thinking that would be so helpful if we could speak the same language.
Stella and Sasha worked individually with the researcher in coaching sessions on how to incorporate real-world scenarios. Stella, a sixth-grade teacher, was interested in how she could incorporate real-world scenarios to assist students in better understanding the creation of ratio tables and to write equations. Sasha, an eighth-grade teacher who also teaches Algebra I for high school credit, wanted assistance in providing rich real-world math tasks that supported vocabulary for her linear function unit. Stella in her coaching session came to the realization that the “constant of proportionality” she taught in tables and on graphs was the rate of change or slope seen in eighth grade content. She noted she never realized how she was building a bridge to future middle and high school math content with her sixth-grade lessons. Stella noted she began making this realization in our workshops when she worked with eighth grade teachers. She said the group really helped her to see the vertical progression, which reinforced the power of the community of practice that TMI established.

Sasha’s realization came in the form of referring to students’ prior knowledge. Sasha had taught only eighth grade and did not realize ratio tables and equations were taught in previous grades. Sasha determined she would use the vocabulary of “constant of proportionality” and “rate of change” interchangeably when she taught her students about equations in the form $y = mx$. She also stated she would make a more concerted effort for her eighth-grade students to note the difference between proportional and non-proportional relationships. Just as Stella noted, Sasha believed working with the group for so many workshops led to her build professional relationships that helped to re-shape her content knowledge.
During one workshop, Stella and Sasha both shared their learnings with their working groups. Other participants learned the “constant of proportionality” many taught in tables, graphs and equations in sixth and seventh grade was “slope” that eighth grade teachers taught. Both noted finding out this connection increased their content knowledge and each would consciously try to set the stage in the classroom to bridge the terminology.

Post-interview responses from all participants echoed what Stella and Sasha learned. The responses were richer with more participants using vocabulary from a variety of grade levels, rather than just the grade level he or she typically taught. All participants in the post-interview noted slope was “a ratio”, “increased and decreased at a constant rate”, “a rate”, “(constant) rate of change” and “a fraction”. Nine of the twelve responses in post-interviews echoed what Sasha’s sentiment of consciously using a variety of grade-level vocabulary to teach their students.

**Instructional strategies that fostered community of practice.** Comparing the participant pre- and post-interview responses showed an increase in use of strategies that fostered a CoP among their students. In many of the pre-interviews, participants noted activities they used to teach proportionality, but most were teacher-led demonstrations. Many participants noted their pedagogy in general was more teacher-directed. Mark, along with several participants categorized, themselves as “procedural teachers” that did not allow much classroom discourse prior to TMI. Jason summarized a change in pedagogy after work with TMI that many participants verbalized. He noted before TMI, he was the “drill sergeant” but afterwards, “it’s a community effort.” Samantha noted TMI had pushed her to “Getting my kids to talk to one another…getting the collaborative
learning. They have their partners and I am always stressing that there is more than one way to do something.” She went on further to say,

Getting that discussion amongst the groups started is a big asset and just learning how to do that. No old school where when I was in school you just stood in front of the classroom and you taught your lesson and you passed the worksheet out. If they didn’t finish it, it was homework. There wasn’t a lot of discussion.

Orchestrating classroom discourse not only increased student engagement, but also increased student learning (Smith & Stein, 2011). Elements of CoP tied in well with the classroom discourse. In the introduction of their book, 5 Practices for Orchestrating Discourse, Smith and Stein (2011) quoted the following from Vygotsky (1978), Lave and Wenger (1991), “Research tells us that complex knowledge and skills are learned through social interaction” (p. 1). They proposed students learn through a process of knowledge construction that required active manipulation and refinement of information and then integration with prior understandings. Social interaction provides us with the opportunity to use others as resources, to share our ideas with others and to participate in the joint construction of knowledge. In mathematics classrooms, high-quality discussions support student learning of mathematics by helping students learn how to communicate their ideas, making students’ thinking public so it can be guided in mathematically sound directions, and encouraging students to evaluate their own and each other’s mathematical ideas (Smith & Stein, 2011, p. 1).

Wenger (1989) noted three dimensions of CoPs: mutual engagement, joint enterprise and shared repertoire. Classroom discourse, in this study seen in classroom observations, manifested itself in these dimensions by students working together on mathematical tasks in which varied solutions or solution paths negotiated through mutual engagement of students working together towards a solution. Joint enterprise was seen
in the collaborative work students completed for a given mathematical task. They worked to make sense of a task and then worked together to gain a solution.

Interestingly, CoPs existed at two-levels in the classroom: small groups and then the whole class. Small groups (or talk partners) negotiated meaning (Wenger called it reification) for how to solve a task demonstrated CoPs at a micro-level. When small groups shared their work with the whole classroom, then a macro-level of CoP was created in which solutions and solution paths were then re-negotiated between their own work and what other small groups found to create a greater understanding, thus student learning. TMI provided instructional strategies that fostered CoP and classroom discourse. Many participants discussed how talk partners, silent teaching and games had made an impact on their classroom practice and increased both their pedagogical and content knowledge.

Talk partners was a strategy introduced in TMI that highlighted the work of Shirley Clarke. In her research, Clarke noted that both student engagement and learning increased when talking partners were utilized for classroom discourse. Clarke suggested students were randomly paired together with partners changing on a regular basis. The teacher posed a question or task in which time was given for individual thinking and then time for partners to compare their thoughts. The teacher randomly called on a student by pulling a card or popsicle sticks with a student name. This process was continued throughout the lesson (Clarke, 2005, 2014).

Talk partners were observed in seven of thirteen classrooms in the second round of observations. Six participants noted positive interactions and increased student engagement and learning. Eli noted he liked, “Getting the kids to talk to one another and
bounce ideas off one another.” Cara noted it “has given me a license to let go of some of the control especially in the classroom.” Student engagement in the form of students actively working on solutions and collaborating on solution paths were seen in classroom observations. Samantha summarized a positive impact many participants who incorporated talk partners felt: “Getting my kids to talk to one another…getting the collaborative learning. They have their partners and I am always stressing that there is more than one way to do something.”

Although the researcher did not assess students for an increase in learning per se, communities of practice were seen in these classrooms. Students were working independently in small groups or talk partners to find solutions. There was discourse and negotiation of meaning through trial and error. The participants were not the teachers the researcher saw in front of the classroom in previous observations, but rather facilitators of the many CoPs within the classroom. For the most part, participants who used talk partners facilitated a discussion over the partner work findings and made connections between talk partners. Unfortunately, not all participants were able to adapt the talk partner strategy in their classroom. Jason and Mark were not able to incorporate it because they felt they were giving up too much control. Jason noted “talk partners turned into what are we doing after school time,” while Mark noted he “just can’t give up that much control”.

While talk partners were not incorporated in all the participants’ classrooms, silent teaching was used and praised by all participants. Silent teaching was introduced to the researcher at the Education Development Center (EDC) in Boston. The researcher taught the strategy to the participants at a workshop. Silent teaching is a strategy in
which the teacher does not talk. Through a series of color-coded steps in a variety of problems, students work together in silence to find patterns and predict the next entry in the problem. The strategy has time for individual thinking and for collaborating with a talk partner. A guide for implementing silent teaching is found in Appendix O. At the end of the lesson (often only 15 minutes), the class worked together to discuss any patterns and determine the algorithm (EDC, 2014).

All participants were to write a silent teaching lesson and share it with the TMI group. A few participants demonstrated their silent teaching lesson during the following workshop or played a video of the lesson from their classroom. All TMI participants observed and provided feedback to improve their silent teaching lessons. Participants gave permission for others to try out their silent teaching lessons in other classrooms and come back with feedback. The researcher also fielded many emails of participants wanting feedback on their lessons. Perhaps participants saw the positive impact silent teaching could make because facilitators for the grant used the workshop as a CoP for participants to refine their silent teaching lesson and collaborate on what mathematical topics were suitable for silent teaching.

Many participants noted the positive impact silent teaching had on their classroom. Marie said silent teaching, “gave everyone their own time to think about what they are doing”. Madelyn noted she had “never seen kids more engaged and more involved in a lesson. Whatever color markers I used...I had to give them the same color pencils. They wanted to follow along”. Stella said her students liked silent teaching because they “were not bombarding with words or there's no pressure to feel like you had to like learn…they could think and then work with others to get the meaning”. Sasha
shared that in her eighth-grade class, the Laws of Exponents is a difficult topic to teach. After several silent teaching lessons, she noted her students had excelled at applying the Law of Exponents.

The student collaborative effort needed for silent teaching lessons was an extension of the CoP that the researcher saw in many classroom observations. Participants noted their classroom CoP extended to incorporating games to build fluency and automaticity. Just as Samantha and Mark noted they moved away from worksheets to more collaborative work like games, many participants noted students working together during games increased their learning.

Regardless of whether participants used talk partners, silent teaching or games as instructional strategies, many participants noted personal growth in the Shift(s) of Classroom Practice they chose. Four of thirteen participants chose Shift 2 “from students working in isolation to collaboratively working” (Bay-Williams et al., 2014, p. 3). Six of thirteen participants in their post-interview noted they chose Shift 6 “from focusing on the right answer to focusing on understanding” (Bay-Williams et al., 2014, p. 3). All three of the instructional strategies mentioned supported Shift 2. Talk partners, silent teaching and games hinged on CoP in the classroom. Although games could be questioned as supporting Shift 6, the other two strategies did support.

Research Question #2: To what extent do middle school mathematics teacher’s perceptions of instructional coaching change after experiencing a coaching relationship?

Study’s definition of coaching. According to the TMI grant stipulations, a facilitator observed and provided feedback to each teacher in the grant. The researcher observed all
study participants and provided feedback on the lesson observed, brainstormed next steps in their lesson progression and fielded any additional questions. These feedback sessions lasted approximately an hour. These observations and feedback sessions were not considered coaching for this study.

Research summed up coaching as:

Partner with teachers to help them incorporate research-based instructional practices into their teaching. They are skilled communicators, or relationship builders, with a repertoire of excellent communication skills that enable them to empathize, listen, and build trusting relationships. (Knight, 2006, p. 30)

The definition of coaching for this study was an interaction of the researcher (coach) with participants that was more than just the required two observations and two one-hour feedback sessions. Coaching, as defined by this study, included any combination of the following: co-teaching, guidance on unit development and assessments, creation of instructional activities/strategies and location of resources/activities. Coaching communication included face-to-face work sessions and email. Six participants did not meet the requirement for coaching and thus were not included in the data analysis for this research question. Those participants were Marie, Mark, Derek, Rose, Eli and Samantha. Marie, Eli, Derek and Samantha were teachers at the same school and did not ask for coaching from the researcher because their school employed a math coach. Mark and Rose were at the same school and did not request any coaching even though there was not a math coach at their school. The researcher approached Mark and Rose both in person at workshops and via email to ask if either needed assistance. Both declined. The remaining eight participants met the criteria and were included the following data analysis.
**Expectations of coaching coming into TMI coaching experience.** The remaining eight participants all had varying amounts of coaching for a variety of purposes during the study. Karen’s pre-interview data was included but not her post-interview data due to prolonged family illness. Going into the study, many participants echoed the same expectations of a math coach regardless if they had experienced interaction with a math or instructional coach. Those expectations were knowledge of grade-level appropriate strategies, provide resources, a people person and good communication. Four participants (Cara, Linda, Madelyn and Stella) had all worked with either an instructional coach or a math coach in the past. The other four participants (Sasha, Karen, Jason and Ellen) had never worked with any type of coach.

The participants who had previously worked with a coach all discussed the positive interactions they had with their coaches. Cara had experience with both an instructional coach and a math coach. Madelyn had experience with an instructional coach only, while Linda and Stella had experience with a math coach only. Cara and Madelyn noted their respective instructional coaches had good command of instructional strategies but did not have a mathematics background, which limited the amount of support and feedback each received. Cara and Madelyn enacted their power by determining the extent to which the feedback provided by the instructional coach was beneficial to their pedagogy and classroom practice. Both noted that the instructional coach worked throughout the building and supported all teachers in all subject areas. Madelyn noted the “coach was tied up too much” and resorted to just handing her books to read instead of sitting down and talking with her. Madelyn valued what the CoP as a coaching relationship could offer but felt disappointed when there was no real discussion
and negotiating of how her pedagogy could be transformed. Madelyn was looking to the coach to possess a greater power than her in order to help her navigate instructional research and its implications for her. Power, in the form of guidance and discussion from the coach, was what Madelyn longed for but it did not come to fruition. Cara said her instructional coach did know useful strategies like Kagan structures along with kinesthetic and interpersonal strategies, however, Cara expressed she did not feel comfortable going to the instructional coach with mathematics questions because the coach did not have a mathematics background. Cara did not feel comfortable going to her instructional coach because she did not see the legitimate power the coach should have possessed in the form of mathematical knowledge. This coach’s perceived deficit on Cara’s part created a wedge between the two, which stifled the cultivation of a true working coaching relationship. Both Cara and Madelyn expressed interest in having a coach they could talk to about mathematics challenges and appropriate strategies. They wanted a coach that could observe and provide each with mathematics-specific feedback for improvement in classroom practice and content knowledge, which is indicative of Foucault’s disciplinary power idea. Cara and Madelyn were explaining their desire for a community in which each could work alongside another professional that could offer advice and support, which is similar to Wenger’s CoP concept of reification. This was lacking for each in their work with an instructional coach.

However, those that worked with a mathematics-specific coach described better experiences in which they changed their practice for the better. Linda, Stella and Cara (in her second experience) each had a mathematics coach at their respective schools. All noted their respective mathematics coach had a good command of the vertical
progression of the mathematics curriculum from kindergarten to high school. Participants exerted their power in determining the level of experience and content knowledge deemed necessary for their perspective coaches to be considered someone of a valued opinion. Each coach satisfied the participants with a variety of strategies offered and mathematical content knowledge. Participant satisfaction enabled them to have a positive perception of the coaching relationship.

Each participant noted that both their pedagogy changed and content knowledge increased because of the work with a previous mathematics coach. Cara noted that an area of growth for her was teaching struggling learners and those in her “response to intervention” (RTI) class. She went to the coach for help with research-based strategies that were appropriate for struggling learners and students with special needs. Cara noted that she felt comfortable with the coach’s knowledge base and so she chose to ask for assistance with RTI. The coach also helped Cara to understand concepts from a foundational, conceptual nature. Cara, with the support and feedback from her coach, said that she was better able to convey the content in such a manner so that she felt she reached more of her students.

Linda noted she was only in her third year of teaching but working with her coach was invaluable. Linda’s coach initially held disciplinary power through observing her teaching. The coach would exert power by sharing her thoughts on what Linda did well and what areas she needed to work on in her teaching. The coach held the power because she grounded her feedback on her own experiences and knowledge base. However, the coach began to share power when she worked collaboratively with Linda to outline the next steps of her professional growth. Through the trusting relationship with the coach
Linda felt empowered to share where she thought her strengths were and how to work on other areas that needed improvement. She noted, “just the combination of two educators coming together and, you know, throwing their ideas together” was important. This sentiment adhered to the CoP idea of two individuals working in tandem to better practice and increase knowledge.

Stella highlighted the many resources and willingness of her coach to talk to her about mathematics challenges. Her coach observed Stella and provided possible target areas of growth. Stella said she liked this model of coaching because she had a say in it and could exert power in what they worked on in coaching sessions. She acknowledged the coach may have more knowledge in certain aspects of classroom pedagogy or content, but the trusting relationship built with coach made her feel equal in her contributions on how to determine her path of growth. In this case, the coach and then circulated to Stella by her having had a choice in coaching topics first held power (choice of coaching topics). Stella was most happy with all the ready-made activities and resources the coach provided her after coaching sessions.

Common themes of observations, feedback sessions and resource compilation were prevalent throughout each participant’s response. However, there were agencies outside of the coaching relationship which demanded coaches perform extra duties that enlarged their responsibilities beyond only working with teachers. Lizzie noted her mathematics coach co-taught lessons with her and took students out to provide tutoring. Stella’s coach was also the mathematics department head and led the professional learning community (PLC) meetings. She noted her coach did several secretarial duties such as ordering supplies, updating curriculum and posting PLC minutes.
Regardless of the extra duties some coaches did, all participants that experienced an instructional coach or mathematics coach explained the position as vital for teacher growth. Even Madelyn, who did not have the most positive experience with her instructional coach, recognized the support a coach could provide. She stated, “I definitely think that coaching is something that needs to happen for everybody, even…not just the first-year teachers or first five-year teachers…everybody needs a coach.” Cara felt the same way as the other participants with a coach, but Stella had the most emotional response of the four participants. Stella emphatically stated coaching was a “mandatory position…literally I mean it has been life-saving.”

These positive interactions participants experienced in previous coaching relationships were vital to the expectations of coaching in TMI. All participants noted that they wanted a coach that was knowledgeable of content and pedagogy and its implications for effective mathematical instruction. This knowledge equated to power. Yet, all participants that had experienced coaching noted that the success of the coaching relationship did not rest on the coach holding the power throughout. Rather, the participants said that it was very important that the coach supported them by teaching them how to make instructional decisions on their own and where to find pertinent resources. The participants did not want someone to tell them how to teach but rather someone who would guide them on how to teach. This was reminiscent of Wenger’s idea of partnership in CoP. Participants wanted to enact their own agency in deciding what fit in their personal pedagogy and what was not congruent with their instructional beliefs. Participants who had never experienced coaching held the hope of positive experiences that those coached participants discussed in their pre-interviews. The four participants
who never worked with a coach were Ellen, Jason, Sasha and Karen. All noted they wanted a coach that was knowledgeable of mathematical content from kindergarten to high school and knew age-appropriate instructional strategies. All said that a coach needed to be a “people person” that was flexible and easy to work with on the job and had good communication and listening skills. Each wanted a coach to observe and provide feedback and support as described by Foucault’s disciplinary power. Participants also noted teachers were very busy and one of the coach’s duties was to provide classroom-ready activities and strategies, so that they did not have to deal with finding them. Participants in this instance wanted the coach to have all the power in dictating the activities for classroom use. It did not matter to participants if they had the agency to choose instructional activities. However, Ellen and Karen noted a coach needed to sit with them and plan lessons. They looked to the coach as the more knowledgeable individual that could guide them in planning lessons. Insecure in their own lesson planning skills and perhaps mathematical knowledge, Ellen and Karen both handed much of the power of planning to the coach. Yet, both still wanted to have power to interject their own ideas in the lesson planning process. Ellen called the interaction a “partnership” which alluded to the underlying principle of CoP. She noted a coach should not be “authoritative”; a coach should not be “a critical spirit, but a helpful and encouraging spirit.”

Jason and Sasha also wanted this partnership but did have some reservations. Jason, a former military officer, noted a coach needed to be “assertive” to get their message across but not too overpowering. Jason was the only participant to say a coach needed to be an accomplished teacher in his/her own right in the pre-interview. He
wanted his coach to “Prove it to me that it works…And once they prove it, then…I buy into it and say…ok”. Here Jason brought up a differential in power and his ability to exercise his power by determining if the coach met his qualifications in content and pedagogical knowledge and ability to command respect. Much like in the military when Jason surrendered his power over to a Staff Sergeant that led him through his daily work, he was willing to surrender over his power in the classroom to a coach that had enough knowledge and skill to offer legitimate feedback and support.

In contrast to Jason, Sasha was somewhat fearful of a coach. She noted the coach’s observations and feedback provided “criticism” for her to get better. A coach’s role was to tell her what she was “doing right and wrong.” Sasha’s language noted her power differential was different than Jason’s idea of coaching. In Sasha’s view, the coach had the power and she was to surrender to the coach’s commands. The use of the words, “criticism” and “doing right and wrong” had the connotation that Sasha felt that the coach had the power in the coaching relationship and may not relinquish it. Sasha noted she wanted the coaching to “help me feel more confident.” She explained her ideal coaching scenario included a coach that provided criticism, feedback and ideas for resources. Sasha noted she wanted “to grow, reflect and change.” She felt a coach could do this for her. It seemed that Sasha wanted a coach that could help her to gain some power in the instructional decisions she made because throughout Sasha’s discourse, it appeared that she thought she had no power.

Each participant noted the coach needed to have clear communication and good listening skills to foster a good working coaching relationship. The call for a coach to have good listening skills alluded to participants wanting the coach not to have all the power but
rather to provide opportunities to empower the participants by listening to their needs. Communication between the coach and participant was important to them because this built a trusting relationship which they felt necessary for them to choose and enact some of the instructional changes the coach suggested.

Participants also noted other coaching duties. Ellen stated she wanted a coach that would sit down with her and look at curriculum documents, unit learning targets and pacing guides. Her curriculum was written, but Ellen felt a second set of eyes could help to better align the curriculum to the standards. This example was different than many the other participants offered. In this example, Ellen had the power. She had created the curriculum based on her content knowledge and understanding of the vertical progression of Standards. She enacted her agency to call in the coach (and her mathematical knowledge) as an individual who could either substantiate her curriculum as valid or provide suggestions for edits. She wanted to have the reciprocal interaction with the coach to negotiate the meaning of the standards and how to best teach them. This activity supports the idea of CoP with its negotiation of meaning in a collaborative setting. In keeping with working together on curriculum, Ellen noted a mathematics coach should also look at assessments.

Curriculum work was not the only duty beyond working with teachers that was presented. Jason and Ellen noted coaches needed to pull struggling students from classes and provide tutoring when possible. Again, this denoted a different view of power in which the participants held the power. The participants decided the students that needed additional tutoring. The coach took the participant suggestions and worked with the students. Ellen went further to say a coach’s influence was measured by student
performance. If student scores were increasing on interim or benchmarking tests, then a coach was successful. This was one of the few examples in which a coach’s performance was evaluated. Quite often participants characterized the coach as the more knowledgeable one who exclusively held the power in the coaching relationship. However, this example provides a glimpse of the idea that the coaches do not always hold the power or engage those coached without questioning their effectiveness.

Regardless of the extra duties or how a coach’s success was measured, all four non-coached participants used the analogy of a mathematics coach to a sports coach. The allusion of a sports coach standing on the sideline and cheering on his or her team was compared to a mathematics coach observing in a classroom and providing feedback to help the next lesson. Initially, the coach held the power through gathering data from observations and informing the participants regarding the instructional moves needed to change their practice, much like a sports coach informs the players of the game plan.

Participants then took the power and determined how to execute the coach’s feedback, similar to how players adhere or not to the sport coach’s game plan. Two quotes that summed up the spirit of the non-coached participant answers were: Sasha said,

Coaching to me is like a basketball coach. They offer you feedback, they put you in, they allow you to grow as a person, they want you do better, and they are willing to sacrifice themselves to get you to the point that you are better.

Ellen offered,

Because a coach’s job on an athletic field is to coach up that player to where they perform better and at the end of the day the scoreboard shows a victory. To me a math coach’s job is to coach up that teacher so that they can perform better so that at the end of the day the students’ scores indicate success.
Non-coached participants had congruent views of power with those coached participants in that the coach quite often initially held Foucault’s idea of disciplinary power and had a great amount of both content and pedagogical knowledge for mathematics teaching. Gathering data and informing participants of their next moves to change their pedagogy situated the power with the coach. In addition to the importance of power, many participants noted that communication was important.

Communication would not be important to participants if they did not want to gain power in the coaching relationship and advocate for coaching tailored to their own needs. Thus, regardless of whether a participant had previously been coached or not, both groups wanted a coach that would help them to gain their confidence and knowledge necessary to take the power and make change their pedagogy. Interestingly, non-coached participants had instances in which they held the power and requested consultation with the coach. Non-coached participants said that a coach could evaluate and suggest edits on pre-existing curriculum the participant had created along with tutoring students the participant said needed assistance.

Analysis of Post-Interviews

In post-interviews, participants reflected on their coaching experience, qualities of a good coach and dynamics of the coaching relationship. Interviews were audio-recorded and then transcribed. Transcripts were divided into three columns: transcript organized by stanzas; thematic analysis codes and researcher’s notes. The researcher analyzed the transcript first by dividing it into stanzas, such as instances that reveal power at work in the coaching relationship or units of complete participant thoughts. An initial reading of the transcript led to a list of codes grounded in how power was
originated, circulated and viewed in the coaching relationship which guided the analysis of the transcript. A set of codes emerged for both the pre- and post-interviews after three readings of the transcripts. A listing of codes emerged from the pre-interviews on coaching, workshops and professional development (Appendix N), while another list of codes emerged from the post-interviews (Appendix P). There were codes that occur in both lists, which served as a way in which the researcher was able analyze the change in participant feelings and perceptions from pre- to post-interviews on particular themes.

The stanzas were then analyzed and coded based on the aforementioned codes. The Researcher’s Notes column allowed the researcher a space for reflection on how particular stanzas and codes did, or did not, exemplify CoPs and the power differential between the researcher (coach) and the participant. Below is an example of the three-column method of analysis the researcher used for pre- and post-interview data:
**Figure 4.1 Example of Three-Column Analysis Tool for Research Question #2**

<table>
<thead>
<tr>
<th>Part VII: Instructional Coaching</th>
<th>Feedback</th>
<th>Tailoring Help</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stanza 1: Expectations</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I: So let's kinda shift to this idea of a math instructional coach. You said that you have not really been coached by a math coach.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S: Right.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I: What types of support do you think an instructional coach should offer to math teachers?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S: I would assume coming in and observing, offering feedback on what we could do better, Having one come in and say what can we do...like finding me professional learning opportunities that fit my need is what I would assume. I don't know.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I: Ok. Ok. Why do you think instructional coaching should be used by math teachers?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S: To get a better understanding of how you can improve in teaching, self-reflection, and see what else is available to you.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I: How would you know that an instructional coach was doing a good job</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S: Offer criticism, offer feedback. Setting down, saying what she did correct. Given ideals of what could be making the lesson better, how we can improve.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Stanza 2: Job Description</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I: If there was a job advertisement for a math instructional coach, what qualities or characteristics do you think that coach would need?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S: Definitely be able to differentiate, like show proof that have been able to produce differentiation in the classroom.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>be able to reach out to other coaches, other districts and find you professional learning opportunities when needed.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Stanza 3: Change in Knowledge</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I: Ok. How do you think teaching and content knowledge would change if you worked with an instructional coach?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S: I think I would be more open-minded of what needed to change, what works and what doesn’t work. I would be more feel confident.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Feedback: Sees coaching as gathering data from classroom observation (coach has the power) in order to tailor learning experiences for her (coach helps to empower the teacher by providing personalized assistance).

Tailoring Help: Coach can help participant to see what is going well and what’s not. Coach gives options for improvement and participant can see what’s out there. Unclear if participant feels she has agency to accept or deny these suggestions.

Strategy Alert: Has requirement coach has to show she has differentiated in classroom. Seems like Sasha wants proof the coach can do what she is sharing. Testing coach’s legitimate power.

Reflection: Feels that coaching would help to give perspective on what and how to change. More confidence = more power. Looking for coach to show to empower herself.
After post-interview analysis and comparison to initial perceptions of coaching, it was found that many expectations participants held about coaching were experienced in their TMI coaching experience. Common intertwined themes were that a coach possessed “know how”, provided support and had good communication skills.

**Know how.** “Know how” as defined by the researcher for coding in this study meant “the coach’s content and pedagogy knowledge was useful in the support and guidance of other math teachers” (Appendix N). All seven participants noted, “know how” as an important characteristic for a coach. However, there were more layers to “know how” than just knowledge. Participants also echoed common themes such as the coach being an experienced teacher along with a command of a variety of instructional strategies that were ready to implement and relevant to both the topic and students the participants were teaching. They also noted coaching helped them to better implement new learnings from the workshops and pushed them toward a more student-centered pedagogy.

Participants often said experience in the classroom was essential for a coach. A coach needed to know both content and how to present it to students. According to participants, the knowledge needed to convey mathematics to students was accomplished when the coach had been teaching for several years. Stella went further to say a coach needed to be “a good teacher in their own right just like because you can kinda impart your own knowledge of classroom routines and you know workings on us”. Many participants noted they felt a coach was the more knowledgeable person (Jason noted the coach needed to be the expert). So, teaching experience allowed the coach to have greater impact on their classroom practice which legitimized the coach. By legitimizing
the coach, participants noted it was easier for them to go to such a legitimized coach with their questions and it built a relationship between them. Ellen conveyed the sentiments of many participants when she said, “It’s really hard to respect someone as a coach if they have not been in the classroom and took care of their business in the classroom”.

Participants perceived the coach as having power because his/her knowledge of content and instructional strategies. The coach initially held the power with the knowledge of the TMI workshop content and strategies. Also, the coach had Foucault’s “disciplinary power” (Ninnes & Burnett, 2003) because of classroom observations. The researcher had made judgements of what were areas participants needed to work on during coaching sessions. However, the participants also had power in this situation by determining if the coach met their expectations of adequate teaching experience and content knowledge. There was not a coaching relationship because the coach facilitated workshops and held coaching sessions. The power rested in the hands of the participants to determine if they were indeed going to follow any of the suggestions that the coach offered to them. If the participants felt the coach met these expectations, then they would turn over some of their power to the coach and determine which suggestions to follow and how to execute them in the classroom. However, if the participants did not think the coach met their expectations, they could have exerted their power and withheld their attention to the coach’s suggestions. In essence, many believe that the coach initially controls the relationship with their power, but it is the participants and their power that determine if there will actually be a trusting, collegial coaching relationship.

Classroom experience allowed the coach to have a capacity of understanding not just content or strategies but how to tailor their knowledge into effective classroom
practice. According to the participants, power is more than just knowledge, but rather the ability to adapt that knowledge to meet the diverse needs of their students. Participants felt this power is not created quickly but evolves from much time spent in the classroom. Just as Foucault noted that power was a process in which individuals adapt to situations to create agency for themselves (Bloome et al., 2008), the coach went through a process of gaining power while in the classroom by strengthening their content knowledge and honing their pedagogy by working directly with students on a daily basis. Participants had the power to determine if the classroom experience was rich enough for them to feel comfortable in asking the coach questions or valuing the coach’s feedback. If the participants did not value the time the coach spent in the classroom, then they could choose to not follow the coach’s suggestions, thus stifling the growth of the coaching relationship.

Participants noted they consulted the coach most often for instructional strategies. Therefore, the coach’s knowledge of a variety of instructional strategies was imperative. Linda and Sasha went further to say the coach also needed a deep understanding of educational research. Jason noted after the coaching, he had a “ton of tools and strategies that I didn’t have before.” However, participants said a coach needed the ability to modify strategies to fit the needs of their classrooms. Ellen, Linda and Jason said that not all students learned the same way; therefore, strategies needed adaptation to fit student needs. Madelyn summed it up saying a coach needs to be “innovative…find different ways to teach something”. Jason added that a coach’s knowledge of strategies needed to include the ability “to understand the limitations of them”. He meant that when an instructional strategy did not produce the intended student learning, a coach needed to be
able to change strategies and adapt them to meet the needs of the learners at hand. Participants demonstrated “know how” by understanding the learning profile of their classroom and recognizing the diverse needs of their students. They had power in understanding the dynamics of their classroom and its learners. Participants continued to hold the power as they determined whether a TMI workshop strategy or coaching session suggestion would enhance student learning opportunities.

Throughout the study’s coaching, participants received support at the classroom level. An example of a coaching instance occurred when Madelyn and Sasha needed assistance with engagement in their classroom. The researcher introduced Madelyn and Sasha to a looping carousel strategy. The researcher noted that this strategy had been used in her classroom and had success in achieving student engagement. In this carousel activity, students moved around the room answering mathematics questions on chart paper. Each chart paper had a number at the top (which was an answer to another problem). Students derived answers and then found the chart paper that had the answer. Students would then solve the problem at the bottom of the piece of chart paper. Students continued solving problems and moving to the various chart papers. Madelyn reflected that this strategy was one she had not seen and it transformed her classroom. Before, students worked in isolation, but this strategy helped her by “getting students up and moving”. She felt she was building more of a community of learners in her classroom. Sasha echoed similar sentiments. The power of choosing topics for coaching sessions had been in the hands of the researcher, however, the researcher began to share power with the participants by providing instructional strategies tailored to the participants’ classrooms. Participants held power by reflecting on their instructional
needs and then asking the researcher for assistance. This give-and-take of instructional strategies illustrated how power circulated in the coaching relationship.

Another layer of “know how” all participants noted was the coach’s ability to use manipulatives and technology. Throughout the study, the researcher fielded questions about how to implement manipulatives like multi-link cubes or technology such as DESMOS into the classroom. Jason’s focus was on pattern blocks used during the workshop to study ratios and proportional relationships. He was unclear how to use the pattern blocks in his class. Instead of meeting in person, Jason emailed questions and the coach provided clarification. The coach also assisted Jason on a pattern block app he used with his students. Although the coach was not there to see the lesson, Jason sent student work and emailed changes he made for the next year. Jason reflected on the experience, “I just wanted to go back and reinforce it more and you helped.”

Ellen, a special needs collaborator, had command of many strategies. She asked for different assistance from the coach. She requested assistance in reviewing her curriculum documents and assessments, along with more support in her content knowledge of proportional reasoning. Ellen relied on the coach’s knowledge of curriculum and its progression to examine how congruent her curriculum was to the CCSSM. Ellen reflected, “help on unit development… was beneficial”. She noted it was nice to have “another set of eyes” to work on her curriculum. The work between Ellen and the researcher exemplified CoP in action. Both were working in tandem to determine the appropriateness of curriculum as they negotiated the meaning of the CCSSM. Although Ellen believed the coach had the “know how”, the coach and Ellen worked together and circulated their knowledge/power, thus creating a newfound knowledge on
Ellen’s curriculum. In addition, Ellen also noted the coach’s “know how” of proportional reasoning helped her to increase her content knowledge of the topic. She stated the following: “I didn’t understand the connections between proportional reasoning and other areas…I had no idea how to really teach it.” She stated her knowledge of proportional reasoning was at a “superficial level”, yet at the end of the study, she felt she taught her students better.

Coaching not only supported the needs of the participants’ individual classrooms, but all coached participants noted coaching helped them with their understanding of material covered in the eight workshops. Cara noted:

workshops were on-going and you have that coach that you can ask questions. And you know the coach will come in and help out and you have the back up and it makes you more confident. It makes you more cognizant of what’s our focus. It’s not like a one and done.

Questions on content were a part of many coaching sessions with the participants. The coach fielded questions over strategies that were unclear from the workshop or modifications on strategies to make them more accessible to a specific participant’s classroom. Regardless of whether the coaching session occurred in person or over email, participants noted they felt more comfortable in implementing the strategies introduced in TMI. The CoP established in the workshop setting transformed into a smaller CoP consisting of just the coach and the participant.

Stella shared a positive experience when she needed help with a silent teaching lesson on integers. She needed more assistance on how to develop and color-code specific patterns in the lesson. The coaching session followed the LMP framework of planning, gathering data and reflection (Bay-Williams, et.al., 2014) and Wenger’s four dimensions of CoP: participation and reification; the designed and emergent; the local
and the global; and identification and negotiability (Wenger, 1989). In the planning stage, Stella and the coach negotiated the patterns needed to create the silent teaching lesson on integers. Power was held by both Stella and the coach by each of them having their own ideas of how the lesson needed to be planned. Each had their own ideas of the important patterns that students should examine in order to learn about integers. Both exerted their power by providing their personal opinions and then shared power when they negotiated how the lesson was to be conducted. Through participation and reification, both worked together to determine the best examples and color-coding for the lesson. In the gathering data stage, Stella used the silent teaching lesson in her classroom. Although the coach was not able to observe, Stella brought back student reflections and reactions to discuss. The designed and the emergent were seen in how the silent teaching lesson linked to student learning according to Stella’s anecdotal records. The reflection stage occurred when Stella and the coach reconvened to discuss the impact of the silent teaching lesson. CoP’s idea of the local and the global were seen when Stella and the coach discussed how the silent teaching lesson supported student learning of the Standards. Further reflection led Stella to ask what other mathematical topics were appropriate for silent teaching lessons, which exemplified the identification and negotiability stage. Stella exerted power by determining that silent teaching was a successful instructional strategy for her students. She enacted her agency by asking the coach if they could create more silent teaching lessons. Other participants’ coaching sessions followed the framework of Stella’s session. Regardless of the mathematical topic participants sought the coach’s “know how”, it was the support given by the coach that made an impression on the participants.
Support. Support in this study was coded as “coaches meet with teachers to provide guidance, modeling and feedback. Also hold them accountable and provide a vision for what’s next to improve their practice” (Appendix N). Just as in “know how” there were many layers to the support participants reported experiencing during the study. Participants characterized their support as a partnership or trusted relationship that allowed them to let go of control in their classrooms and felt empowered to negotiate meaning of curriculum and strategies. All coached participants used the word “partnership” to describe their coaching experience. Even though all coached participants noted they wanted a coach that was more knowledgeable and even sometimes referred to as an “expert”, they also wanted a partnership with the coach. The idea of a partnership signified the circulation of power and a CoP. Partnership took the form of feedback from classroom observations, co-teaching experiences and jointly planned coaching sessions. Although the coach had the disciplinary power established by her position in the grant, participants exerted their power by agreeing to participate in coaching establishing what Wenger’s CoP noted as “mutual engagement”. Through the learning at both the workshop and coaching levels, participants negotiated meaning of new strategies and how they were beneficial or needed adaptation for their particular classroom use. Exemplifying Foucault’s idea that power was a system of unequal points exerting, which were seen in the relationships among the participants and between the coach. Each had an opportunity to enact agency, or not, and to negotiate meaning or not. When both agreed to work together a “joint enterprise” was established. It was through this mutual engagement and joint enterprise that the participants and the coach
established a “shared repertoire” of TMI strategies that participants chose to make a part of their pedagogy and personal instructional practice.

Both Cara and Sasha reflected on feedback they received after an observation by the coach. Cara remembered a time when the coach observed a lesson in which students were working on open-ended mathematics task. The students were struggling with the task and Cara was perplexed as to why since the students had completed similar tasks in the past. Cara recollected, “we had done similar activities in the past. It was just a commonsense expectation but they were struggling...” The coach suggested a rubric could help guide students’ work on the task. Both Cara and the coach sat down after the lesson and created a rubric together. This partnership helped Cara to use an instructional strategy she had forgotten. Cara’s reaction after the rubric creation was, “Wow that would be helpful.”

Sasha recalled both classroom observations and a co-teaching experience with the coach. She initially thought a coach only gave feedback on written lesson plans, but she was pleasantly surprised when the coach came to her room on three different occasions at Sasha request. Mutual engagement was high because Sasha requested the coach multiple times and the coach came to her classroom to assist. Sasha remembered the coach coming in and providing immediate feedback on lessons she used for the next class. She appreciated the multiple classes in a row the coach observed. After the initial day in which the coach stayed for four class periods, Sasha and the coach determined some areas for Sasha to focus on for improvement. As stated in an earlier section, Sasha and the coach determined she needed a new engagement strategy. The coach planned the looping carousel strategy and sent it via email to Sasha. After a few email exchanges
with edits, both felt the lesson was ready for student-use. The coach came back to
Sasha’s class that day and they worked together to present the lesson. Sasha
characterized the partnership developed between her and the coach as “I know a lot of
teachers kinda feel threatened with someone coming in their classroom and taking over.
And you never took over. You were my co-person.” The relationship formed between
Sasha and the researcher through multiple communications and co-teaching helped to
break down personal barriers and power was shared between the two.

Linda recalled a similar experience in which she requested coaching on geometry
because of her uneasiness with the eighth-grade standards. Some would say that
uneasiness was a sense of powerlessness, yet Linda’s ability to recognize her limitations
and ask for help demonstrated her power of self-reflection and agency. She noted
conversations with the coach over email several times to negotiate what topics and
strategies Linda needed to improve her geometry instruction. During a day-long
coaching experience tailored to Linda’s needs, she and the coach discussed the meaning
of the standards, strategies that promoted student learning/engagement and assessment
ideas. Linda stated, “And I felt like it was perfect as far as what I needed to think about
for this coming year and what I needed to work on”. This tailored coaching experience
was not possible if the coach held the power of what topics were covered. Initially, Linda
said she felt the coach should decide what she needed. Yet at the end of the study, Linda
felt empowered to make instructional requests and decisions on her own. Through joint
enterprise with the coach, Linda began to establish her shared repertoire of TMI strategies
and their adaptations for her classroom use, thus transforming her pedagogy.
Other participants also discussed their feelings of empowerment after the coaching experience. All coached participants admitted they held on to some of the traditionalist teaching practices such as lecture, rote memorization and textbooks. Often their students worked at their seat in isolation with limited mathematics discussions or collaborative work. It was this belief in traditionalist teaching practices that many participants initially held which gave them power to not take suggestions from the coaching sessions or TMI workshops. Jason, a retired military officer, summarized the instructional shift many coached participants experienced when he stated, “my classroom has changed from drill sergeant to it’s a community effort”. Coached participants experienced the benefits of CoP at the workshop level in which they collaborated and negotiated the meaning of sound instructional practice and the standards. Then, the participants experienced another level of CoP when they interacted with the coach to negotiate how to implement TMI learning and strategies in their classrooms. It seemed the idea of CoP was now becoming part of their classroom practice. Additionally, their experience with the power initially held by the coach and then circulated among them led many coached participants to say they wanted their students to do more discussion and sense-making on their own. Madelyn characterized her classroom as “kids working more to become a community and talk to one another, they can express what they think about…being able to explain their reasoning”.

Cara admitted she was a traditionalist and had adhered to her district policy of gradual release model exclusively in her classroom. She held the power in initially choosing not to implement many of the TMI strategies because of her traditionalist beliefs. However, after the study, Cara said that TMI and coaching gave her “a license
to let go of some control in her classroom”. She went on further to say, “It’s okay! You can do something new and it’s all good”. She felt like she was doing a better job of getting her students to think about the “why” instead of the “how”. Ellen echoed Cara’s sentiments. Ellen noted that before the study, she taught mathematics topics in isolation. Now after TMI workshops and coaching on curriculum creating that joint enterprise in a CoP, Ellen felt she had a better understanding of how topics progressed across grade levels. As it related to her students, Ellen stated, “I am not teaching them for a test, I am teaching them for the long term.”

Students were also foremost on Jason’s mind. He noted the coaching experience allowed him “the ability to let go.” Many may read that this experience was Jason and other participants letting go of power, yet in actuality, they still had power. Choosing to allow students more of an active role in their learning was a way in which Jason and the other participants enacted their agency by changing the dynamics of their pedagogy. Jason recalled a time when the coach helped him to “let go.” He was struggling with how to help students understand constant of proportionality. The coach suggested using multi-link cubes with students. He recalled, “You helped me to get them to use their hands and not just them sitting there getting a lecture for forty-three minutes because they don’t have that attention span.” Jason noted he had more confidence in using a variety of strategies after his coaching experience. This level of comfort was also noted by Stella who said, “It’s hard for me to step outside of the box and try new things but it has made me better and willing to do that.” Linda and Madelyn also felt they were more knowledgeable of instructional strategies and adapting them to their own classroom needs. Linda went further to say her knowledge of instructional strategies and their
adaptations were a direct result of negotiated conversations about mathematics with others.

Ellen’s stance agreed with Linda’s position. Ellen stated when like-minded people were together, “There is power in that to have a conversation you are able to have”. Sasha said, “Having that coach to push, talk and discuss was a huge benefit. And I was able to pick up ideas from you and she helped me to become a better teacher and push me further.” This quote exemplified the meaning of reification in a CoP. Cara continued the theme of support and negotiated meaning with, “So when you have that constant coaching…we are still going to keep on working on this…you need that support to refocus.” Coaching provided participants with the chance to reflect and refine their learning of content and instructional practices. However, the experience would not have been as successful if it were not for good communication.

**Good communication.** Good communication was the building block for the relationships that participants built with the coach. Jason stated:

> Communication is just key. I have to feel comfortable coming to him or her and saying…I don’t know how to do this. And help me to figure out how to get me to move forward. I have to have a relationship.

Linda noted, “if you have that relationship, then you are always building and communicating and helping each other.” Many participants held the same stance. Good communication was important if there was a CoP established in the coaching relationship. This relationship that was built and cultivated with the coach had other requirements too. Characteristics of good communication, as outlined by the participants included: relatable, good listener and conversationalist. They also noted good
communication in coaching sessions was not limited to face-to-face meetings, but emails and virtual file exchanges that were helpful in their growth during the study.

Relatable was a characteristic many coached participants talked about in their post-interviews. Ellen noted a coach was “approachable and who doesn’t talk down to people and doesn’t act like they are better than others”. Cara and Linda noted a “good listener” made the coach more relatable. These characteristics made the coach a strong conversationalist. Initially, what a conversationalist meant for this study was that the coach facilitated the ebb and flow of a conversation in a coaching session. However, as the coaching relationship deepened, many participants felt the conversation became two-way. Both the coach and the participants felt comfortable to enact their power deciding when to listen and when to talk. At times the participants led the conversation and the coach listened and provided feedback and vice versa. This exemplified the circulation of power between coach and participant and helped establish the CoP. Sasha noted the coach never “threw it in your face and said here, do this.” The coach took time to explain content and strategies and fielded any of her questions. This was unlike Madelyn’s experience with her school-level mathematics coach that handed her books and never had a conversation about them. Cara noted this behavior was not acceptable in the coaching relationship. She stressed the coaching relationship had to have good communication as defined by the participant and the coach, otherwise “there could be a lot of misconceptions and it really doesn’t help.”

Throughout all the coached participant responses, communication was key to them feeling comfortable with content and instructional strategies. They trusted the coach to help them. Both Jason and Cara said the coach fielded their questions and made
them more confident in incorporating new instructional strategies. All participants said this comfortable relationship transferred to virtual coaching. Perhaps it was because this study was conducted during Year 3 of the grant and relationships had been previously established in the workshops and through coaching sessions. CoPs on multiple levels were established and working, so emailing and exchanging files virtually was considered an advantageous endeavor. Participants saw this form of communication as coaching.

The coach lived at least an hour from each of the coached participants. Meeting face-to-face regularly was nearly impossible. Therefore, the coach communicated often through emails in the form of check-ups. Email also negotiated the content of upcoming face-to-face coaching sessions. If a participant had a question about how to implement an instructional strategy learned at a TMI workshop, often they sent an email to the coach. The coach responded with feedback. If a participant needed a resource or wanted another strategy, the coach would gather the resources and send them via email. Sasha and Madelyn consulted with the coach on their looping carousel strategy before its implementation. Emails were exchanged to determine the problems along with room set-up instructions. Both noted in their post-interviews that this arrangement was time-saving and very helpful. Madelyn added that she did not know if consulting on-line would have been as beneficial if there was not a relationship first.

**Conclusions**

Results and analyses did answer Research Question #1, yet results do not fully answer Research Question #2. First, the study focused on the extent to which teachers’ content knowledge changed after on-going workshops were paired with instructional coaching. Quantitative findings concluded that overall, there was a gain in the pre-test
mean to post-test mean for virtually all participants. Upon examination of each sub-group’s pre-to post-test means, it was found: males outperformed females; participants with more than six years teaching experience outperformed those with less teaching experience; participants who had been affiliated with TMI for the duration of the grant outperformed those new to the TMI grant; participants attending 4-5 workshops (out of 8) outperformed those attending 6-7 workshops or 8 workshops and participants with more than the grant-required two hours of coaching outperformed those that experienced the minimum amount of coaching time as stipulated by the TMI grant.

When examining the individual knowledge types defined by the DTAMS, it was found that Knowledge Type III (problem-solving using deductive, inductive, proportional and spatial reasoning) increased the most for all groups and sub-groups. This across-the-board increase was attributed to the focus TMI workshops had on how proportional reasoning was manifested in multiple representations in a variety of real-world contexts. However, Knowledge Type IV (knowledge unique to teaching mathematics with multiple representations and knowledge of student misconceptions and strategies for intervention) decreased or had no change from pre-test mean to post-test mean for virtually all groups and sub-groups. This was attributed to the “strategy-over load” in which TMI offered a multitude of strategies but did not offer sufficient time for participants to understand how to apply the strategy appropriately to their classroom. Also, TMI did not allow enough time for participants to bring in student work to analyze. Results suggest that the pairing of workshops and instructional coaching can have a positive effect on pre- to post-scores. This study’s data collection did not yield a definitive answer on the effect that workshops had independent of the instructional coaching and vice versa.
Qualitative data supported the change in participants’ content knowledge. It was found through analysis of themes in participant responses that most were able to provide richer post-interview responses to the math questions with a variety of multiple representations, vocabulary usage that demonstrated vertical progression and multiple TMI strategies to help their students answer similar math problems. Second, the study examined if there was a change in participants’ perceptions on coaching after experiencing a coaching relationship. Those who had not experienced a coaching relationship were apprehensive at first but did note the coaching was a positive experience of support and advocated for more opportunities to experience coaching. Overwhelmingly, responses included that coaching was a “partnership”. This idea resonated with Wenger’s CoP. Through thematic analysis it was noted that many participants attributed a good coaching relationship with the ability to circulate power (knowledge or choice) between the coach and the participant.
CHAPTER V
DISCUSSION, CONCLUSIONS AND IMPLICATIONS

This explanatory sequential mixed methods study addressed the following research questions:

1. To what extent do middle school mathematics teachers’ content knowledge on proportional reasoning change after on-going workshops and instructional coaching?

2. To what extent do middle school mathematics teacher’s perceptions of instructional coaching change after experiencing a coaching relationship?

Through a series of workshops and instructional coaching, participants’ performance on a content-based pre- and post-tests were analyzed along with the change participants had in their perception of coaching by examining pre- and post-interviews. Findings concluded overall participants’ scores increased from the pre- to post-test and participants’ perceptions of coaching were favorable as an added PD support.

Discussion and Conclusions

The study found that participant content knowledge did change after experiencing the TMI grant which paired on-going workshops with instructional coaching. Quantitatively speaking, there was a gain from the pre-test mean to post-test mean for virtually all participants. These results were qualitatively supported in the themes and richness of participant interviews over DTAMS questions. Participants were able to provide richer post-interview responses to the math questions with a variety of multiple representations, vocabulary usage that demonstrated vertical progression and multiple TMI strategies that fostered communities of practice in their own classroom to help their students answer similar math problems.
The study also found that coaching was beneficial for support in changing their content knowledge. Whether a participant had or had not experienced coaching prior to this study, it was found at the end of the study that virtually all participants felt coaching was a positive experience of support and advocated for more opportunities to experience coaching. Themes of “know how”, good communication and support echoed the sentiments that coaching was a “partnership”, which reinforced Wenger’s CoP. Also, the idea of circulation of power resonated with the post-modernist view.

**Content knowledge.** At initial glance on the DTAMS, thirteen out of fourteen participants increased their overall score from the pre- to the post-test. All participants and all participant sub-groups (male and female; years of teaching experience; duration of TMI membership; number of workshops attended and hours of coaching) also had increases in their overall scores from the pre- to post-test. The combination of a series of workshops coupled with instructional coaching made a difference in the participants’ content knowledge.

The three sub-categories that are of importance in this study are duration of TMI membership, number of workshops attended and hours of coaching. Research states that teachers who receive multiple hours of PD on focused topics with active learning in a community of learners have gains in teacher knowledge (Ball & Cohen, 1999; Garet, Porter, Desimone, Birman & Yoon, 2001; Hargreaves & Fullan, 1992; Wilson & Berne, 1999; Yoon et al., 2007). This study supports those findings. When examining the number of workshops, the highest post-test score and second highest percent of change from pre- to post-test scores were with participants that had attended all eight of the workshops. The participants who attended 4-5 meetings had the greatest percent of
change but had the lowest scores on both the pre- and post-tests in this sub-category. The more TMI workshops attended, the better the scores. For those participants who had been in TMI for the duration of the project, their pre- and post-scores were higher along with their percentage of change than those participants who only had one year in TMI. The longer a participant was a part of TMI, the better the scores. As for coaching, those participants that had more than the required two hours of coaching had both higher pre- and post-test scores than those participants that had the minimum two hours of coaching. However, those that had the minimum amount of coaching had a slightly greater percent of change versus those participants with more than two hours coaching. Although it was not as clear cut, if a participant had more than the required two hours of coaching, scores generally were higher.

Further examination of individual DTAMS scores showed trends that could lead to some common characteristics of participants who scored higher on the post-test. After rank ordering each participant score from the highest to lowest, it was found that the top 4 scoring participants had the following in common:

- three of the four participants had more than the required two hours of coaching as stipulated by the TMI grant;
- three out of the four attended all eight of the meetings; and
- four participants had been a part of TMI for the duration of the grant.

Another layer of analysis in this study was the audio-recording of participants’ answers to mathematical tasks from the DTAMS. After an analysis of their answers, the following themes emerged in their post-interviews: increased use of multiple representations to justify their answers; knowledge and use of varied, multiple grade-
level vocabulary; and increased knowledge and use of various instructional strategies. These themes were consistent with research supporting the notion that teachers need to have both content and pedagogical content knowledge that is more specialized than what is needed for non-teachers (Hill, Schilling & Ball, 2004; Shulman, 1986). Math teachers need specialized mathematical knowledge “to generate representations, interpret student work, or analyze student mistakes” (Hill, Schilling & Ball, p. 27).

Multiple representations were a major theme seen in participants’ responses which was also a concept highlighted in six of the eight workshops. During the workshops, participants completed hands-on activities and labs that generated data. Facilitators then worked with participants to help them see how multiple representations were connected. Participants spatially learned how proportionality, slope and y-intercept were connected. This focus on spatial connections of multiple representations led to high scores in Knowledge Type III on the DTAMS. Knowledge Type III includes knowledge application to real-world problems with the use of various forms of reasoning (such as spatial) to solve problems. Knowledge Type III had the greatest increase among all subgroups.

Unfortunately, not all Knowledge Types showed overall growth. Knowledge Types II and IV were problematic for many of the participants. Knowledge Type II dealt with connections, representations and a deep understanding of concepts and procedures while Knowledge Type IV dealt with knowledge specific to teaching mathematics. There were many opportunities for work with connecting representations during workshops, yet results did not support the workshops’ focus. Knowledge Type IV and its lower numbers were understandable. Through interviews, many participants said there were so many
instructional strategies and they did not have enough time to completely understand each strategy or to know how to incorporate them into their teaching. This strategy-overload coupled with limited time for participants to self-reflect could have decreased the scores on Knowledge Type IV. Although participant performance on Knowledge Type II and IV were not as favorable, many measures showed participant content knowledge increased.

**Coaching.** Regardless of the hours of coaching or previous experience with a coach, participants noted that an effective coach should have high levels of content and pedagogical knowledge along with support and good communication. All participants wanted a sense of community in which the coach initially had the power/knowledge. However, as the coaching relationship grew, they wanted more autonomy over the content of the coaching sessions.

Eight out of fourteen participants had coaching beyond the required two hours as stipulated by the TMI grant. From those eight participants, four had worked with a coach before and four had not. Regardless of the reality or the expectations of working with a coach, participants noted that a coach could be helpful. Those who worked with a coach had experiences with both instructional coaches (those that work with all subject areas) and a mathematics-specific coach. Those that worked with a mathematics coach previously reported more satisfaction in the mathematics-specific feedback and instructional strategies. The four participants who had no experience previously with a coach all wanted the same as those that had experienced a coach: feedback, a sense of community and support to change their practice.
Post-interviews revealed three coaching themes: know how, support and good communication. All participants noted both in pre- and post-interviews a coach needed to have “know how”. A coach had “know how” if they had experience in the classroom and knowledge in content, instructional strategies, manipulatives and technology. “Know how’s” effects were two-fold. First, participants noted that the coach needed to be the more knowledgeable in order to provide the mathematics-specific support and, second, to legitimize their position (of power) in the coaching relationship. By holding the knowledge, the coach held the power in the initial formation of the coaching relationship. The participants wanted the knowledge/power to transform their content knowledge and pedagogy.

Power began to circulate in the coaching relationship when the coach conducted classroom observations and assisted participants in choosing a shift from the LMP framework to guide coaching sessions. The coach had disciplinary power by collecting and analyzing classroom observation data. However, over time, the coach dictated next steps less and asked the participants to self-assess what support they needed. This gesture began the circulation of power and thus a CoP was established.

A CoP was a culture that all participants described in their interviews. The themes of support and good communication reinforced the idea of CoP in the coaching relationship. Support initially was characterized as a coach’s ability to field questions and suggest alternate strategies. However, as the coaching relationship progressed, many participants noted it became a partnership. This change in terminology signified the circulation of knowledge/power in the coaching relationship. The idea of a partnership was more compatible with CoPs. Communication was not just limited to face-to-face
coaching sessions, all participants said the emails and virtual file exchanges were effective forms of communication. Participants noted good communication was also instrumental in maintaining and deepening their coaching relationship.

**Implications for Professional Development Providers**

For PD providers, this study provided teachers’ views on effective PD. The importance of community and self-reflections were two characteristics participants said were effective and the data supports it. Participants liked having time to talk with other teachers. TMI had teacher participants who taught sixth through ninth grade. Many participants noted they enjoyed working with other teachers and learned a great deal from them. Participants talking with both grade level peers and teachers of other grade levels helped increase the vertical knowledge of mathematical concepts, especially vocabulary, for the entire group. In post-interviews, many participants revealed they felt TMI was a family or a community in which they felt valued. Participants also stated they liked time for self-reflection. However, TMI did not offer this opportunity to them often enough. Many noted that time to think about the strategies and their placement in their curriculum would have been more beneficial. PD providers need to keep these characteristics in mind and plan for increased participant time to reflect on how workshop learning can be translated into classroom practice. Time also needs to be devoted to teacher share-out and conversations on how the workshop learning can be tailored to the needs of their specific students and classrooms.

**Implications for Coaches**

This study found a coach was not someone who came in with a mandated charge (power), but rather someone who came in and worked with teachers to determine the best
path of self-improvement. Themes like establishing trust, support and communication showed that teachers wanted a community, but they also wanted a coach to listen to their needs, fears and frustrations over content, pedagogy and students. It seemed coaching was like a curricular counseling session. Additionally, a coach possessed a command of both content and pedagogy. The findings from this study support the idea of a community approach in which teachers work together (whether with a coach or peers) rather than working in isolation. Many the roles and responsibilities evidenced in this study were outlined in research on coaching (Becker, 2001; Campbell & Malkus, 2013a; Chval et al., 2010; McGatha, 2008). Coaches need to be aware of the variety of roles and responsibilities they have and be flexible with exercising them with teachers.

**Implications for the Researcher**

The researcher directly benefited from the study’s findings. The researcher is currently employed as both a mathematics coach and a PD provider. Mathematics coach findings inform the interactions the researcher has with teachers. The researcher experienced a great deal of planning, observing and conferencing with teachers. As a result of the findings, the researcher has realized coaching is providing support and building confidence in all teachers the researcher has contact with at school. Before the study, the researcher generally gave out suggestions for strategies and made classroom visits, but the procedures of collecting data from classroom observations and conferencing with the teacher were non-existent. Before the findings from this study, the researcher generally had a plan for coaching that was not necessarily tailored to the needs of the teachers. After this study, the researcher now more fully understands the critical
importance of conferencing and empowering teachers through coaching that can lead to a gain in teacher content knowledge and implementation of diverse instructional strategies.

As a PD provider, the researcher now more fully understands the importance of specific time devoted to teacher reflection. When the researcher was in the classroom, time was always devoted to students writing and reflecting on the day’s lesson, yet that crucial instructional practice was not translated to the teachers the researcher interacted with in PD workshops. Since the ending of the TMI grant period, this concept of teacher reflection and providing time for teachers to share and critique each other’s work is being built into all workshops the researcher facilitates.

Future Research

This study focused on the power of coaching and its effectiveness when paired with PD workshops. More studies with a greater number of participants need to be conducted to see the effect of coaching and pairing it with PD workshops has on teacher content knowledge and perceptions of coaching. Even though student achievement was not a focus of this study, additional studies need to be conducted to measure the effects of coaching on student success and achievement.

Additional data was collected from high school teachers that was not used for this study. Perhaps future studies could examine the effectiveness of coaching and PD workshops on teachers at elementary, middle and high school. Teacher knowledge, pedagogy and coaching are critically important components to have an instructionally sound classroom.
APPENDIX A

Description of Types of Knowledge Measured by DTAMS (CRMSTD, 2016)

Type I: Memorized Knowledge

This mathematics knowledge is learned by rote and employs memorization. It includes memorized knowledge of definitions, procedures, or rules. Teachers with this knowledge can perform by rote skills, apply rules, and give definitions.

Type II: Conceptual Understanding

This mathematics knowledge is conceptual in nature. It includes a deep understanding of mathematical concepts, procedures, laws, principles, and rules. It is knowledge of connections and relationships among concepts. It is often associated with meaning. Teachers with this knowledge can give examples/non-examples and identify properties/characteristics of mathematical concepts. They can compare, contrast and represent mathematical concepts and generalizations in multiple ways. They can explain and create mathematical procedures and represent them in multiple ways.

Type III: Problem Solving & Reasoning

This mathematics knowledge is higher order in nature. It includes applying knowledge to solve problems and real-world applications. Teachers with this knowledge can reason informally and formally, conjecture, validate, analyze, and justify. They can use deductive, inductive, proportional, and spatial reasoning to solve problems.

Type IV: Pedagogical Content Knowledge

This mathematics knowledge is unique to teaching mathematics. It represents the mathematics knowledge that teachers use in the act of teaching. It includes knowledge of the most regularly taught topics in mathematics, the most useful forms of representation
of those ideas, the most powerful analogies, illustrations, examples, explanations and
demonstrations. Teachers with this knowledge can identify student misconceptions about
mathematics and provide strategies to correct them. Teachers can derive activities that
promote understanding, reasoning, and proficiency. They can provide examples,
analogy, models, or representations to help students understand mathematical concepts
or procedures.
APPENDIX B

Semi-Structured Pre-Interview Protocol for TMI Mathematics Teachers Who
HAVE Experienced Instructional Coaching:

Participants: TMI teachers who agreed to participate in data collection for dissertation

This semi-structured interview includes questions that will address the following research
question:

*To what extent do middle school mathematics teacher’s perceptions of instructional
coaching change after experiencing a coaching relationship?*

1. Demographic information: years of teaching, current and previous teaching
   assignments

2. Why did you decide to become a mathematics teacher?

3. How do you think students best learn mathematics?

4. What types of experiences have you had with professional development in your
   career?

5. Have you ever been a part of a cohort or group that has had multiple professional
development meetings that focused on a common topic or goal?
   a. If so, please describe this professional development experience.
   b. If not, what benefits could you see from a professional development that was
      structured so that it met multiple times and focused on a common topic or
      goal?

6. Have you ever received professional development that was math-specific in focus
   (besides TMI)?
a. If so, please describe this professional development. What benefits did you
gather from the experience?

b. If not, what benefits could you see from a math-specific professional
development opportunity?

7. What were your expectations when told you were going to work with an instructional
cootch?

8. How did the instructional coach compare to your expectations?

9. Describe your coaching experience. (Try to gain information on the following sub-
questions)
   A. What was the duration of the coaching relationship?
   B. How were coaching sessions conducted? (length and frequency of sessions)
   C. What topics were covered?
   D. How were topics for the coaching sessions chosen? (coach or teacher
      chosen?)

10. How if at all has your teaching and content knowledge changed as a result of the
    instructional coaching?

11. Is there anything else you would like to add about your coaching experience or
    coaching in general?

12. Researcher will administer six selected DTAMS items that focus on proportional
    reasoning items.
APPENDIX C

Semi-Structured Pre-Interview Protocol for TMI Mathematics Teachers Who HAVE NOT Experienced Instructional Coaching:

Participants: TMI teachers who agreed to participate in data collection for dissertation

This semi-structured interview includes questions that will address the following research question:

To what extent do middle school mathematics teacher’s perceptions of instructional coaching change after experiencing a coaching relationship?

1. Demographic information: years of teaching, current and previous teaching assignments

2. Why did you decide to become a mathematics teacher?

3. How do you think students best learn mathematics?

4. What types of experiences have you had with professional development in your career?

5. Have you ever been a part of a cohort or group that has had multiple professional development meetings that focused on a common topic or goal?
   a. If so, please describe this professional development experience.
   b. If not, what benefits could you see from a professional development that was structured so that it met multiple times and focused on a common topic or goal?

6. Have you ever received professional development that was math-specific in focus (besides TMI)?
a. If so, please describe this professional development. What benefits did you
gather from the experience?

b. If not, what benefits could you see from a math-specific professional
development opportunity?

7. What types of support do you think an instructional coach should offer to mathematics
teachers?

8. Why do you think instructional coaching could be used with mathematics teachers?

9. How would you know if an instructional coach was doing a good job?

10. How do you think your teaching and content knowledge would change if you worked
with an instructional coach?

11. Is there anything else you would like to add about your thoughts instructional
coaching?

12. Researcher will administer six selected DTAMS items that focus on proportional
reasoning items.
APPENDIX D

Post-Interview Protocol for TMI Mathematics Teachers

Participants: TMI teachers who agreed to participate in data collection for dissertation

This semi-structured interview includes questions that will address the following research question:

To what extent do middle school mathematics teacher’s perceptions of instructional coaching change after experiencing a coaching relationship?

Questions for this interview tie to Gee’s seven building tasks for language to which discourse analysis tries to answer. Those tasks include establishing the following: significance, practices (activities), identities, relationships, politics (distribution of social goods), connections and sign systems (knowledge).

1. In pre-interviews, TMI participants provided characteristics they thought made for an effective instructional coach. The top 10 characteristics from these interviews include the following: (provide a card for interviewee to view for ease of answering question)

What do you think are the top 3 characteristics of an effective instructional coach and why?

<table>
<thead>
<tr>
<th>Good teacher in their own right</th>
<th>Has knowledge of variety of strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multiple years of teaching experience</td>
<td>A people person</td>
</tr>
<tr>
<td>Innovative</td>
<td>Fair and unbiased</td>
</tr>
<tr>
<td>Understands current educational research</td>
<td>Good communication</td>
</tr>
<tr>
<td>Understands how to use manipulatives/technology</td>
<td>Good Listener</td>
</tr>
</tbody>
</table>
2a. Describe a typical coaching session you experienced during TMI.

(IF interviewee did not participate in skip to #3)

_Probe for the following: how topics were chosen, who chose the topics, duration of coaching, was there a shared dialogue or did coach talk most of time,_

a. Which activities/routines did you find beneficial?

b. Which activities/routines did you not find beneficial?

2b. To what extent do you feel that the coaching you received over the past eleven months did or did not change your pedagogy?

_Probe for specific instances of change such as strategies, questioning, use of manipulatives, assessments, technology, etc._

i. And your content knowledge as it relates to proportional reasoning?

_Probe for instances of multiple methods in which to solve instead of just cross-products, understanding that proportional reasoning is seen in a variety of topics such as transformations, linear and non-linear functions, NAGS rule etc._

2c. You were given a set of instructional shifts we could focus on during our time in the coaching relationship. You chose __________________. What effect, if any did choosing this instructional shift shape your experience with an instructional coach?

3. You participated in no coaching during this eleven-month period. What was/were the reasons why you did not participate in the coaching?

4. A study from Murray, Ma and Mazur (2009) noted that coaching is “one teacher is not viewed as more of an expert than the other. Instead, they work in a partnership.”
Explain how accurate or inaccurate this statement characterizes your relationship with the coach in this study or your beliefs on coaching.

5. You stated in your previous interview that you thought the role of the instructional coach was to (insert some text from previous interview). Compare and contrast your experience during this past six months to the expectations you held.
(If no coaching, frame as “…Compare and contrast your beliefs of coaching.”)

6. TMI had not only coaching but monthly meetings that focused on content and instructional strategies. To what extent did or did not the monthly meetings change your pedagogy?

_Probe for specific instances of change such as strategies, questioning technique, use of manipulatives, assessments, technology etc._

   a. and your content knowledge as it relates to proportional reasoning?

_Probe for instances of multiple methods in which to solve instead of just cross-products, understanding that proportional reasoning is seen in a variety of topics such as transformations, linear and non-linear functions, NAGS rule etc._

7. What were the benefits of pairing on-going workshops with instructional coaching?

What were any challenges or barriers you experienced?

8. Is there anything else you would like to add about your experience with this sustained professional development that paired on-going workshops with instructional coaching on proportional reasoning?

9. Researcher will administer parallel DTAMS proportional reasoning items from pre-interview.
APPENDIX E

Characteristics Most Often Cited in Pre-Interview

Good teacher in their own right

Multiple years of teaching experience

Innovative

Understands current educational research

Good listener

Has knowledge of variety of strategies

A people person

Fair/unbias

Understands how to use manipulatives/technology

Good communication
APPENDIX F

Institutional Review Board Approval Letter

TO: Jamie-Marie L. Wilder-Miller
169 General Cleburne Drive
Richmond, KY 40475
Phone #: (859) 749-0884

FROM: Chairperson/Vice Chairperson
Non-medical Institutional Review Board (IRB)

SUBJECT: Approval of Protocol Number 15-0318-P4S

DATE: May 27, 2015

On May 21, 2015, the Non-medical Institutional Review Board approved your protocol entitled:

Instructional Coaching and Its Effects on Middle School Mathematics Teachers' Perceptions of Coaching and Content Knowledge: A Mixed Methods Study

Approval is effective from May 21, 2015 until May 19, 2016 and extends to any consent/assent form, cover letter, and/or phone script. If applicable, attached is the IRB approved consent/assent document(s) to be used when enrolling subjects. [Note, subjects can only be enrolled using consent/assent forms which have a valid "IRB Approval" stamp unless a special waiver has been obtained from the IRB.] Prior to the end of this period, you will be sent a Continuation Review Report Form which must be completed and returned to the Office of Research Integrity so that the protocol can be reviewed and approved for the next period.

In implementing the research activities, you are responsible for complying with IRB decisions, conditions, and requirements. The research procedures should be implemented as approved in the IRB protocol. It is the principal investigator’s responsibility to ensure any changes planned for the research are submitted for review and approval by the IRB prior to implementation. Protocol changes made without prior IRB approval to eliminate apparent hazards to the subject(s) should be reported in writing immediately to the IRB. Furthermore, discontinuing a study or completion of a study is considered a change in the protocol’s status and therefore the IRB should be promptly notified in writing.

For information describing investigator responsibilities after obtaining IRB approval, download and read the document "PI Guidance to Responsibilities, Qualifications, Records and Documentation of Human Subjects Research" from the Office of Research Integrity's IRB Survival Handbook web page (http://www.research.uky.edu/ori/IRB-Survival-Handbook.html#P1responsibilities). Additional information regarding IRB review, federal regulations, and institutional policies may be found through ORI's web site (http://www.research.uky.edu/ori). If you have questions, need additional information, or would like a paper copy of the above mentioned document, contact the Office of Research Integrity at (859) 257-9428.

[Signature]
Chairperson/Vice Chairperson
APPENDIX G

Institutional Review Board Continuation Approval Letter

Continuation Expedited Review
Modification Approved: Extension

Approval Ends
March 29, 2017

TO:
Jamie-Marie Wilder-Miller,
169 General Cleburne Drive
Richmond, KY 40475
PI phone #: (859)749-0884

FROM:
Chairperson/Vice Chairperson
Non-medical Institutional Review Board (IRB)

SUBJECT:
Approval of Protocol Number 15-0318-P4K

DATE:
April 8, 2016

On March 30, 2016, the Non-medical Institutional Review Board approved your protocol entitled:

Institutional Coaching and Its Effects on Middle School Mathematics Teachers' Perceptions of Coaching and Content Knowledge: A Mixed Methods Study

Approval is effective from March 30, 2016 until March 29, 2017 and extends to any consent/assent form, cover letter, and/or phone script. If applicable, attached is the IRB approved consent/assent document(s) to be used when enrolling subjects. [Note, subjects can only be enrolled using consent/assent forms which have a valid "IRB Approval" stamp unless special waiver has been obtained from the IRB.] Prior to the end of this period, you will be sent a Continuation Review Report Form which must be completed and returned to the Office of Research Integrity so that the protocol can be reviewed and approved for the next period.

In implementing the research activities, you are responsible for complying with IRB decisions, conditions and requirements. The research procedures should be implemented as approved in the IRB protocol. It is the principal investigator's responsibility to ensure any changes planned for the research are submitted for review and approval by the IRB prior to implementation. Protocol changes made without prior IRB approval to eliminate apparent hazards to the subject(s) should be reported in writing immediately to the IRB. Furthermore, discontinuing a study or completion of a study is considered a change in the protocol's status and therefore the IRB should be promptly notified in writing.

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Chairperson/Vice Chairperson
APPENDIX H

Call for Participants Presentation

RESEARCH PARTICIPATION REQUEST

Call for research participants

Request for Participation

- Interested in how coaching can help teachers with content knowledge

- Through research, I have found there are many models and definitions of coaching

- Through our conversations in TMI...we all have differing definitions of coaching. I want to study this in our group.
Instructional Coaching and Its Effects on Middle School Mathematics Teachers’ Perceptions of Coaching and Content Knowledge: A Mixed Methods Study

Jamie-Marie Miller—Candidate for PhD in STEM Education at University of Kentucky

Objectives

• How do middle school mathematics teachers’ content knowledge on proportional reasoning change after serial professional development meetings and instructional coaching?

• How do middle school mathematics teacher’s perceptions of instructional coaching change after experiencing a coaching relationship?
Study Design

- Beginning in August, we will start looking closer at proportional reasoning.
- Our look at proportional reasoning will take approximately four-six months.
- Monthly meetings and coaching sessions will cover various facets of proportional reasoning

As a TMI Participant...

- Attend monthly meetings
- Participate in discussions and activities
- Complete any homework assignments such as readings, projects or bringing in student work
- Provide feedback about meetings and services provided
- Periodically take the DTAMS for grant reporting purposes
What I Am Requesting From You

- Permission to use your DTAMS scores as pre and post data points for a secondary analysis
- Audio record a pre and post interview on your thoughts and perceptions on proportional reasoning and the effects of coaching on your content knowledge and pedagogy
- Audio record coaching sessions at your schools

Important Points to Note

- ALL YOUR DATA (DTAMS SCORES AND INTERVIEWS) WILL BE CODED UNDER NUMERIC CODES...YOUR NAMES WILL BE TAKEN OFF SO THAT DATA WILL NOT BE TRACED BACK TO YOU!
- If you decide to participate in the dissertation data collection and later want to withdraw, you will still be a part of the TMI grant with no penalty
- If you do not participate in the data collection for the dissertation, you will not be penalized in the TMI grant
- You will not receive any rewards for participation
What's In It For You?

- Grants such as TMI are funded through state and federal agencies. All grant-funded projects must have research-based strategies. You are helping to advance research for more effective teacher professional development in the future.

Consent Forms

- If you agree to participate in the dissertation data collection, please read and sign the consent form
- If you would like some more time to consider, please feel free to contact my committee members and sign the consent next month
- If you do not want to participate, no forms are required
My Dissertation Committee

- Advisor: Dr. Margaret Mohr-Schroeder
  - m.mohr@uky.edu
- Dr. Carl Lee
  - lee@ms.uky.edu
- Dr. Molly Fisher
  - Molly.fisher@uky.edu
- Dr. Christine Mallozzi
  - Christine.mallozzi@uky.edu

DTAMS
APPENDIX I

Consent to Participate in a Research Study

Instructional Coaching and Its Effects on Middle School Mathematics Teachers’ Perceptions of Coaching and Content Knowledge: A Mixed Methods Study

WHY ARE YOU BEING INVITED TO TAKE PART IN THIS RESEARCH?
You are being invited to take part in a research study about how instructional coaching for middle school mathematics teachers can change their perceptions of coaching and their content knowledge. You are being invited to take part in this research study because you are a participating teacher in the Timely Mathematical Interventions (TMI) grant that is facilitated through the College of Education at the University of Kentucky. If you volunteer to take part in this study, you will be one of about twenty-eight people to do so.

WHO IS DOING THE STUDY?
The person in charge of this study is Jamie-Marie Louise (Wilder) Miller who is a graduate student in the Department of STEM Education. She is being guided in this research by Dr. Margaret Mohr-Schroeder. There may be other people on the research team assisting at different times during the study.

WHAT IS THE PURPOSE OF THIS STUDY?
Instructional coaching has become a professional development intervention that many Kentucky school districts employ to help teachers with their work. By doing this study, we hope to learn how exposure to instructional coaching changes the perception that some middle school mathematics teachers have about coaching and the effects that it has on the teachers’ content knowledge.
ARE THERE REASONS WHY YOU SHOULD NOT TAKE PART IN THIS STUDY?

Individuals should not participate if he/she feels uncomfortable being interviewed or having the interview audiotaped.

WHERE IS THE STUDY GOING TO TAKE PLACE AND HOW LONG WILL IT LAST?

The research procedures of audio-recorded interviews will be conducted at Partnership Institute for Math/Science Education Reform (PIMSER) office along with audio-recorded coaching sessions and follow-up interviews at your home school. Data collection will occur from June 2015 to September 2016.

WHAT WILL YOU BE ASKED TO DO?

As a participant in this research study, you will be interviewed at the beginning this study on your perceptions of instructional coaching and how you think it will affect your content knowledge. After the study, you will be interviewed on what you believe the change instructional coaching has brought to your content knowledge. All participant interviews and instructional coaching sessions will be audiotaped. In addition to interviews, participants agree to allow the researcher access to their pre- and post-assessment data from the Diagnostic Teacher Assessments in Math and Science (DTAMS) for Algebraic Ideas sub-test from Year II of the project along with initial baseline data that was gathered in Year I administration of the DTAMS.
WHAT ARE THE POSSIBLE RISKS AND DISCOMFORTS?
To the best of our knowledge, the things you will be doing have no more risk of harm than you would experience in everyday life. You may find some questions we ask you (or some procedures we ask you to do) to be upsetting or stressful. If so, we can tell you about some people who may be able to help you with these feelings. In addition to the risks listed above, you may experience a previously unknown risk or side effect.

WILL YOU BENEFIT FROM TAKING PART IN THIS STUDY?
There is no guarantee that you will get any benefit from taking part in this study. Your willingness to take part, however, may, in the future, help society as a whole better understand this research topic.

DO YOU HAVE TO TAKE PART IN THE STUDY?
If you decide to take part in the study, it should be because you really want to volunteer. You will not lose any benefits or rights you would normally have if you choose not to volunteer. You can stop at any time during the study and still keep the benefits and rights you had before volunteering. If you decide not to take part in this study, your decision will have no effect on the quality of meeting content, instructional coaching or materials received.

IF YOU DON’T WANT TO TAKE PART IN THE STUDY, ARE THERE OTHER CHOICES?
If you do not want to take part in the study, there are will be no repercussions. You will still receive the same training and materials as those that chose to participate in the study.

WHAT WILL IT COST YOU TO PARTICIPATE?
There are no costs associated with taking part in the study.
WILL YOU RECEIVE ANY REWARDS FOR TAKING PART IN THIS STUDY?

You will not receive any rewards or payment for taking part in the study.

WHO WILL SEE THE INFORMATION THAT YOU GIVE?

We will make every effort to keep confidential all research records that identify you to the extent allowed by law. Your information will be combined with information from other people taking part in the study. When we write about the study to share it with other researchers, we will write about the combined information we have gathered. You will not be personally identified in these written materials. However, the DTAMS does ask for the last four digits of your Social Security number. Upon receiving your DTAMS pre- and post-tests, the External Evaluator for the PIMSER TMI Project will assign a new numeric code for each participant so that the last four-digits of the Social Security number will not available for viewing. These unique numeric codes will be used to organize the pre- and post-tests data along with the audio and transcripts of interview and coaching session data. We may publish the results of this study; however, we will keep your name and other identifying information private.

We will make every effort to prevent anyone who is not on the research team from knowing that you gave us information, or what that information is. Data (pre- and post-assessment scores along with audio files and transcripts) will be stored on the researcher’s password protected computer. Also, data will be stored in paper form and on an external hard drive that will be locked in a locked fireproof filing cabinet in a locked office. All signed consent forms and data will be kept on file for six years after the project’s completion. The data will remain in the researcher’s office for the duration of time. All participants’ names will be kept separate from the data and stored based on the
unique numeric code that was assigned to protect the identity. The only individuals who will have access to the data files will be the researcher and her faculty advisors.

We will keep private all research records that identify you to the extent allowed by law. However, there are some circumstances in which we may have to show your information to other people. For example, the law may require us to show your information to a court to tell authorities if you report information about a child being abused or if you pose a danger to yourself or someone else. Also, we may be required to show information which identifies you to people who need to be sure we have done the research correctly; these people would be from such organizations as the University of Kentucky.

**CAN YOUR TAKING PART IN THE STUDY END EARLY?**

If you decide to take part in the study you still have the right to decide at any time that you no longer want to continue. You will not be treated differently if you decide to stop taking part in the study.

**WHAT ELSE DO YOU NEED TO KNOW?**

There is a possibility that the data collected from you may be shared with other investigators in the future. If that is the case the data will not contain information that can identify you unless you give your consent or the UK Institutional Review Board (IRB) approves the research. The IRB is a committee that reviews ethical issues, according to federal, state and local regulations on research with human subjects, to make sure the study complies with these before approval of a research study is issued.
Contacting Research Subjects for Future Studies

Do you give your permission to be contacted in the future by Jamie-Marie Louise (Wilder) Miller regarding your willingness to participate in future research studies about instructional coaching or mathematics content?

☐ Yes  ☐ No  □□□□□□□□ Initials

Partnership Institute for Math and Science Education Reform is providing financial support and/or material for this study.

WHAT IF YOU HAVE QUESTIONS, SUGGESTIONS, CONCERNS, OR COMPLAINTS?

Before you decide whether to accept this invitation to take part in the study, please ask any questions that might come to mind now. Later, if you have questions, suggestions, concerns, or complaints about the study, you can contact the investigator, Jamie-Marie Louise (Wilder) Miller at 859-749-0884. If you have any questions about your rights as a volunteer in this research, contact the staff in the Office of Research Integrity at the University of Kentucky between the business hours of 8am and 5pm EST, Mon-Fri. at 859-257-9428 or toll free at 1-866-400-9428. We will give you a signed copy of this consent form to take with you.

_________________________________________  __________________
Signature of person agreeing to take part in the study  Date

_________________________________________
Printed name of person agreeing to take part in the study

_________________________________________  __________________
Name of (authorized) person obtaining informed consent  Date
APPENDIX J

TMI Classroom Observation Instrument

MATHEMATICS CLASSROOM OBSERVATION INSTRUMENT

Leadership by Design (TMI Version)

Level/Class _____ Lesson Title ___________ Length of Observation ______

Total # Students _____ Gender: M______F __ # Minority ____ # Inclusion _____

This is a [ ] regular ed classroom [ ] co-taught class [ ] resource room

Learning Objective of the Lesson

I. LESSON OVERVIEW

A. Learning Objective of the Lesson (Mark all that apply)

□ Clearly communicated by the teacher using multiple means □ Communicated orally only □ Communicated in writing only □ Student activities consistent with the lesson objective(s) □ Student activities not consistent with the lesson objective(s) □ Lesson objective communicated but not clear □ Lesson objective not communicated

B. Major Instructional Resource used in the lesson observed (Mark 1, 2, 3…with 1 meaning “primary/predominant resource influencing instruction”) )

□ Textbook
□ Other Print Materials (worksheet, manual, etc.)
□ Technology based presentation media
□ White Boards
□ Manipulatives (List) ________________
□ Calculators (Not Graphing)
□ Computer
□ Graphing Calculator (TI-Nspire)
□ Mathematics Centers
□ Math Games □ Number Lines
□ Other (List) ________________

C.1. Content Delivery (Mark all that apply)

□ Age/grade level appropriate
□ Content presented is accurate
□ One or more content errors
□ Student misconception not Corrected

D. Place in Instructional Sequence (Mark 1, 2, 3…)

□ Introduction of new concept
□ Develop conceptual understanding
□ Apply concept to new situation
□ Review concept or procedure
□ Assess student understanding

E. Seating Arrangement for Lesson (Mark 1, 2, 3…)

□ Large group
□ Pairs/Talk Partners
□ Small groups: Same Task Different Task
□ Individuals working on same task
□ Individuals working on different tasks

C.2. Content Focus (Mark 1, 2, 3…)

□ Number/Computation □ Measurement □ Probability □ Statistics
□ Arithmetic □ Algebra □ Geometry □ Pre-calculus/Calculus

C.3. Communication

□ Consistently used accurate and effective communication; vocabulary is clear, correct and appropriate.
□ Generally used accurate and effective communication; occasional use of inappropriate vocabulary.
□ Consistently used inaccurate and ineffective communication and/or inappropriate vocabulary.
II. INSTRUCTIONAL OVERVIEW (Mark 1, 2, 3… in each section with 1 meaning “primary/predominant resource influencing instruction”)
A.1. Instructional Strategy
☐ Teacher lecture  ☐ Teacher demonstration  ☐ Teacher-led discussion  ☐ Individual assistance
☐ Student presentation  ☐ Small group discussion  ☐ Students Solving Problems  ☐ CRA (Concrete-Representational-Abstract) Manipulative and/or Representation used:___________
☐ Silent Teaching  ☐ Other ________
A.2. Instructional Strategies Appropriate for Content and Contribute to Student Learning
☐ Used instructional strategies that were clearly appropriate for the content/processes of the lesson.
☐ Used instructional strategies that were generally appropriate for the content/processes of the lesson.
☐ Used instructional strategies that were questionable or inappropriate for the content/processes of the lesson.
B. Student Activity
☐ Listening to/observing teacher presentation  ☐ Participating in discussion (teacher led or small group)
☐ Conducting mathematics investigation  ☐ Completing a skills/practice worksheet (recall or comprehension)
☐ Higher-level problem-solving assignment  ☐ Using hands-on materials to solve problems/ verify solutions
☐ Applying math to realistic problems  ☐ Assignment/answering questions from text/other resources
☐ Taking test  ☐ Sharing solutions or strategies  ☐ Using computer software program  ☐ Using the Internet for research  ☐ Using computer for inputting/analyzing data
Comments:

III. QUESTIONING
A. Quality of Questions (Mark ONLY ONE box, record examples of each)
☐ Questions were mostly narrow or convergent focusing on factual recall or one word responses (e.g.,______________)
☐ Questions were mostly broad or divergent and stimulated higher cognitive student responses (e.g.,______________)
☐ Appropriate balance of factual recall and higher cognitive questions
☐ No questions were asked by teacher or posed through the activity being conducted
B. Questioning Techniques (Mark all that Apply)
☐ Students are encouraged to ask questions of each other and/or the teacher  ☐ Questions stimulated higher level and divergent thinking  ☐ Appropriate wait time  ☐ All students have an opportunity to respond  ☐ Most students have an opportunity to respond  ☐ Only a few students have an opportunity to respond
☐ Teacher provides focused, descriptive, and qualitative feedback to student responses*
☐ Teacher provides general feedback of limited value to students
☐ Teacher provides feedback but not beneficial to students or no feedback at all
IV. TEACHER CREATES AND MAINTAINS LEARNING CULTURE
(Mark one response for each section)
A. Communicates High Expectations
☐ Significant/challenging lesson objectives; teacher consistently communicates confidence in students’ ability to achieve.
☐ Challenging objectives; some communication of confidence in students’ ability to achieve.
☐ Minimal objectives for students; rarely or never communicates confidence in students’ ability to achieve.

B. Establishes a Positive Learning Environment
☐ Clear conduct standards; awareness of student behavior; responded appropriately/respectfully.
☐ Conduct standards but some inconsistency in monitoring and response to student behavior.
☐ No established conduct expectations; minimal or no monitoring; inappropriate responses to behavior.

B. Student Involvement (Mark only one)
☐ All or nearly all students demonstrate interest and were engaged
☐ Majority of students demonstrate interest, were engaged
☐ Approximately equal numbers of students interested/engaged and not interested/not engaged
☐ Majority of students uninterested or apathetic; generally not engaged
☐ Nearly all of the students were uninterested and not engaged

C. Classroom Management (Mark only one)
☐ Classroom orderly, no student disruptions (or minor) that impaired learning environment
☐ Classroom generally orderly but some student disruptions that required disciplinary action
☐ Classroom disorderly, frequent student disruptions that seriously impaired the learning environment

D. Values and Supports Student Diversity
☐ Recognized and consistently responded to the diversity in the class (gender, ethnicity, academic and physical abilities); Consistently used or attempted to use strategies to address the needs of all students;
☐ Recognized but inconsistently responded to the student diversity; used or attempted to use some different strategies to address the needs of different students
☐ Little or no recognition or response to student diversity and individual needs; used the same approach for all students.

E. Fosters Mutual Respect Between Teacher and Students and Among Students
☐ Always treated all students with respect; encouraged and clearly expected students to treat each other with respect.
☐ Generally treated students with respect; some encouragement of students to treat each other with respect.
☐ Did not show respect or concern for students; little or no encouragement of students to treat each other with respect.
F. Provides a Safe Environment for Learning
☐ Classroom environment was emotionally and physically safe for students at all times.
☐ Classroom environment was emotionally and physically safe for students most of the time.
☐ Classroom environment was not emotionally and/or physically safe for students.

V. ANALYSIS OF INSTRUCTION LEADING TO THE DEVELOPMENT OF HIGHER LEVEL SKILLS (Mark one response.)

☐ Students solve meaningful mathematical or realistic problems through explorations or investigations that can be generalized to allow them to make valid conjectures (#14), determine strategies to solve problems (#13), evaluate logical consistency (#15) and/or justify/verify solutions (#16).
☐ Students discover a mathematics phenomenon using a planned activity that requires using a problem-solving strategy, collecting and analyzing data, and/or making connections between mathematics ideas or strands.
☐ Students learn a mathematics concept using a preplanned activity that provides a definitive procedure and requires a specific response to be correct.
☐ Students are not involved in any type of problem solving/inquiry/investigative activity.

VI. TEACHER ASSESSES AND COMMUNICATES LEARNING RESULTS (Mark one response each section)
A. Uses Formative Assessments Aligned with Learning Objectives
☐ Formative assessment strategies fully aligned with learning objectives; obviously used to adjust instruction.
☐ Formative assessment strategies aligned with learning objectives; appeared to be used to adjust instruction.
☐ Formative assessment strategies were generally aligned with learning objectives; not clear if or how used to adjust instruction.
☐ Formative assessment to support student learning not clearly aligned with objectives; appeared to be done without intention or done for compliance.
☐ No assessment strategies used even though formative assessment was needed to determine level of student learning.

B. Uses a Variety of Formative and/or Summative Assessments to Measure Student Learning
☐ Used assessment strategies which provided all students several opportunities to demonstrate learning.
☐ Used assessment strategies which provided most students opportunities to demonstrate learning.
☐ Used some assessment strategies which provided some students opportunities to demonstrate learning.
Limited use of assessment strategies which provided minimal opportunities for students to demonstrate learning.

No assessment strategies used even though formative assessment was needed to determine level of student learning.

C. Adapts Formative and/or Summative Assessments to Accommodate Diverse Learning Needs and Situations.

- Assessment strategies were obviously adapted to accommodate student diversity and diverse learning needs.
- Assessment strategies appeared to be adapted to accommodate student diversity and diverse learning needs.
- Some attempts to adapt assessment strategies to meet diverse needs however not successful for all students.
- Limited attempt to adapt assessment strategies to accommodate student diversity or diverse student needs.
- No assessment strategies used even though formative assessment was needed to determine level of student learning.

VII. PHYSICAL SETTING/CLASSROOM ENVIRONMENT (Mark all that apply)

- [ ] Mathematics manipulatives/tools evident
- [ ] Mathematics displays promote learning
- [ ] Class sets of calculators available
- [ ] Ongoing mathematics projects in evidence
- [ ] Mathematics student work displayed
- [ ] Adequate resources for lesson are present
- [ ] Outside interruptions (#_____ )
- [ ] Classroom adequate size for student number
- [ ] Adequate storage for resources/materials/equipment
- [ ] Furnishings allow for activity-based instruction (CBL, etc)
### Learning Culture

<table>
<thead>
<tr>
<th>Observation Comments:</th>
<th>Coaching Comments:</th>
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<tbody>
<tr>
<td><strong>Growth Mindset</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Learning Power</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Talk Partners</strong></td>
<td></td>
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</tbody>
</table>

### Instructional Strategies

<table>
<thead>
<tr>
<th>Observation Comments:</th>
<th>Coaching Comments:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CRA</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Manipulatives:</strong></td>
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<tr>
<td><strong>Algebra Tiles</strong></td>
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<tr>
<td><strong>Pattern Blocks</strong></td>
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<tr>
<td><strong>Other</strong></td>
<td></td>
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<tr>
<td>Silent Teaching</td>
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<tr>
<td>----------------</td>
<td>----------</td>
</tr>
<tr>
<td>Number Line</td>
<td></td>
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<tr>
<td>Other</td>
<td></td>
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<tr>
<td><strong>Technology</strong></td>
<td></td>
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<tr>
<td>TI-Nspire</td>
<td></td>
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<tr>
<td>Desmos</td>
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Appendix K

Instructional Shifts

2.2 Planning Tool: Shifts in Classroom Practice Self-Assessment

Place an X along each continuum that best represents your classroom practice. After marking each continuum, consider which shift is a priority for a coaching cycle (and beyond).

**Shift 1: From same instruction toward differentiated instruction.**
- Same instruction for all students. → Differentiated instruction, but same learning outcomes for all students.

**Shift 2: From students working individually toward community of learners.**
- Students work individually on tasks and seek feedback from teacher on reasonableness of strategies and solutions. → Community of learners as a part of which students hear, share, and judge reasonableness of strategies and solutions.

**Shift 3: From mathematical authority coming from the teacher or textbook toward mathematical authority coming from sound student reasoning.**
- Correctness of solution is determined by seeking input from teacher or textbook. → Correctness of solution is based on reasoning about the accuracy of the solution strategy.

**Shift 4: From teacher demonstrating “how to” toward teacher communicating “expectations” for learning.**
- Teacher demonstrates the way to solve a problem and helps students solve the problem that way. → Teacher facilitates high-level performance by sharing learning goals and expectations for products that demonstrate learning.

**Shift 5: From content taught in isolation toward content connected to prior knowledge.**
- Content presented independent of its connections to what has been previously learned. → Content presented in ways that give explicit attention to making connections among mathematical ideas.

**Shift 6: From focus on correct answer toward focus on explanation and understanding.**
- Discussions and classroom routines focus on student explanation of solutions and whether they are correct. → Discussions and classroom routines focus on student explanations addressing why an answer is (or isn’t) correct.

**Shift 7: From mathematics-made-easy for students toward engaging students in productive struggle.**
- Mathematics is presented in small chunks, with help provided, so that students reach solutions quickly and without higher-level thinking. → Teacher poses tasks and challenges students to persevere and attempt multiple approaches to solving problems.
APPENDIX L

Workshop Feedback Form

Timely Mathematical Interventions (TMI)

Evaluation September 24, 2015

Grade Level: □ MS – 6th □ MS – 7th □ MS – 8th □ High School □ Multiple Grades _

1. The information provided regarding 3 Types of Effective Questioning was very beneficial in helping me to learn how to create a variety of learning experiences for my students in my mathematics classroom.

   Strongly Agree □ □ □ □ □ Strongly Disagree

2. I feel confident that I can write open-ended questions in the forms suggested by the 3 Types of Effective Questioning for classroom use.

   Strongly Agree □ □ □ □ □ Strongly Disagree

3. I feel I am lacking resources and materials to adequately teach proportional reasoning.

   Strongly Agree □ □ □ □ □ Strongly Disagree

4. I feel I struggle in my own understanding of proportional reasoning that affects the effectiveness of my teaching.

   Strongly Agree □ □ □ □ □ Strongly Disagree

5. I teach multiple methods in solving problems involving proportional reasoning beyond the use of cross-products.

   Strongly Agree □ □ □ □ □ Strongly Disagree

6. The information regarding proportional reasoning was beneficial. I feel that I can teach proportional reasoning using multiple methods.

   Strongly Agree □ □ □ □ □ Strongly Disagree

7. I see the benefits of using Math Stations as an instructional strategy.

   Strongly Agree □ □ □ □ □ Strongly Disagree

8. I see the benefits of using table top as an instructional strategy.

   Strongly Agree □ □ □ □ □ Strongly Disagree
9. In regard to the instructional strategies that you were introduced today, please list 2 specific strategies that were especially valuable to you for teaching students struggling in mathematics. Please provide a brief statement as to why you considered those strategies valuable.

1.

2.

10. What areas of proportional reasoning introduced or taught during this workshop do you need/would like to have additional professional development or coaching?

11. What were the take-aways or surprises you found while completing the Standards Dig on proportional reasoning?

12. What suggestions would you offer to help improve the learning experiences you have in TMI for next month?

13. Overall, how would you rate today’s professional learning?  (Please check only one)

☐ Exceptional  ☐ Very Good  ☐ Good  ☐ Not very good  ☐ Poor

14. The instructors were…(please check all that apply)

☐ Knowledgeable  ☐ Well prepared  ☐ Well organized  ☐ Aware of the needs of classroom teachers

15. The mathematics content taught and the materials provided to me will be (check all that apply)

☐ Useful as I prepare math lessons  ☐ Provide good background information to support my teaching

☐ Help me differentiate instruction for my students  ☐ Not very useful to me

16. Any additional comments about today’s work or TMI, please feel free to share those in the space below:
APPENDIX M

Template for Member Check

Thank you so much for your willingness to participate in my dissertation data collection. I have transcribed the interview and attached it to this email. At your leisure, please read over the transcript to see if you agree what I have written captures our interview.

If you agree that the transcript is accurate and you agree with the information that it contains please reply back to the email saying that you have read the transcript and agree to its content, you give permission for me to use it for analysis in my dissertation.

If you do not agree with the content, please email me back with a list of changes that I need to make. I will make those changes and then resend it to you for your approval.

Again, thank you for your willingness to participate. Upon agreement of this transcript, your name will be replaced with a randomly generated code and your identity will be held separate from this data.
### APPENDIX N

**Thematic Analysis Codes from Pre-Interviews on Coaching, Workshops and Professional Development**

<table>
<thead>
<tr>
<th>Code</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beyond Coaching</td>
<td>Duties that took on more secretarial like facilitating agenda from office that is not math-specific to filling out paperwork.</td>
</tr>
<tr>
<td>Collaborative Discussion</td>
<td>Discussion among teachers with or without math coaches that look at best practices, the “how to’s” and watch out fors when implementing strategies, student performance and other topics pertinent to the teaching and learning of mathematics</td>
</tr>
<tr>
<td>Freedom of Choice</td>
<td>Ability of teacher to choose the PDs they feel are pertinent to their classroom content, topics they want to learn about in coaching sessions or discuss in PLCs.</td>
</tr>
<tr>
<td>Know How</td>
<td>Coach’s content and pedagogy knowledge that is useful in supporting and guiding other math teachers.</td>
</tr>
<tr>
<td>Math Over Pedagogy</td>
<td>College courses, PD or philosophy that places more emphasis on the symbol manipulation and “act of doing math” is more important than learning how to teach mathematics to others.</td>
</tr>
<tr>
<td>No Choice</td>
<td>Teachers have no choice in PD due to district regulations or no choice on topics for their coaching sessions.</td>
</tr>
<tr>
<td>Not A Math Coach</td>
<td>Other mentors or coaches such as instructional coaches that are not specifically math knowledgeable.</td>
</tr>
<tr>
<td>One Time PD</td>
<td>PD that is a one-time only offering that has no follow-up.</td>
</tr>
<tr>
<td><strong>Open Pedagogy</strong></td>
<td>Math instruction that offers multiple entry points and solution paths. Conceptual understanding is valued more than algorithms.</td>
</tr>
<tr>
<td>------------------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>PD is N/A</strong></td>
<td>PD is not applicable due to presented content is not congruent with current grade level taught or it does not meet the professional needs of the teacher.</td>
</tr>
<tr>
<td><strong>Reflection</strong></td>
<td>Teachers to think about their practice and its impact on student performance as evidenced by student work/test scores. Reflection can be by self, with math coach or group of math teachers (or any combination of aforementioned).</td>
</tr>
<tr>
<td><strong>Relevance</strong></td>
<td>Adapt resources or strategies for own classroom guidance either self-guided, with coach’s guidance or with group of math teachers (or any combination of aforementioned).</td>
</tr>
<tr>
<td><strong>Resources</strong></td>
<td>Strategies, books, technology or other items that are used in classroom instruction.</td>
</tr>
<tr>
<td><strong>Strategy Alert</strong></td>
<td>Ideas for specific strategies that have made an impact on their practice or impact student learning.</td>
</tr>
<tr>
<td><strong>Student Relations</strong></td>
<td>Teachers trying to connect with students to assist them in their learning.</td>
</tr>
<tr>
<td><strong>Support</strong></td>
<td>Coaches meet with teachers to provide guidance, modeling, and feedback. Also hold them accountable and provide a vision for what’s next to improve their practice.</td>
</tr>
</tbody>
</table>
Appendix O

A Guide to Implementing Silent Teaching Routine

Silent teaching hinges on Mathematical Practice #8:

<table>
<thead>
<tr>
<th>Task Orientation</th>
<th>Strategies Employed</th>
<th>Why We Do It?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Begin task in silence</td>
<td>Silence! Individual think time</td>
<td>Silence and color allows for students to focus on the repetition Understanding repetition can lead students to develop their own shortcuts</td>
</tr>
<tr>
<td>Have examples pre-written</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use color to highlight repeated process</td>
<td></td>
<td></td>
</tr>
<tr>
<td>When students are ready...hand markers over to them to fill in missing portions of problems</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Recognizing Repetition</th>
<th>Strategies Employed</th>
<th>Why We Do It?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Talk with a partner by using one of the sentence frames:</td>
<td>Think Pair Share</td>
<td>Time for self-reflection and self-assessment of thought. Sentence frames help students to form thoughts and strengthen communication skills.</td>
</tr>
<tr>
<td>I was paying attention to ____</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Every time _____, then ______</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I noticed _____ always _____</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Circulate and listen to student thought</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Assessing Reasoning</th>
<th>Strategies Employed</th>
<th>Why We Do It?</th>
</tr>
</thead>
<tbody>
<tr>
<td>A pairs shares thinking</td>
<td>Individual Think Tim Sharing Out Think Pair Share</td>
<td>Students describe thoughts again which solidifies thinking and allows others to compare their thoughts to what is stated. Engaging and allows for more conversation Depending on the students...there can be several rounds of sharing to discuss various methods and uses of repetition.</td>
</tr>
<tr>
<td>Ask another group to rephrase what the previous group shared</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prompt students to listen/look for how repetition was used and a shortcut</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Give 10 to 15 seconds to think on shortcuts for INDIVIDUALS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Give 20 to 30 seconds for PAIRS to share ideas</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ask 1 to 2 students to explain reasoning. Have them discuss why the approach works and strategies they used</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reflection</th>
<th>Strategies Employed</th>
<th>Why We Do This?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individuals respond to a reflection stem:</td>
<td>Individual writing time Think Pair Share</td>
<td>Learning consolidation through summarizing leads to better communication. Sharing aloud can build confidence and refine thinking</td>
</tr>
<tr>
<td>Next time I look for repetition, it will be helpful to ____</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The next time I look for a shortcut, I will look for ____</td>
<td></td>
<td></td>
</tr>
<tr>
<td>You can make mathematical generalizations by ____</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Students write down their short cut and how they found it before leaving class.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix P

Thematic Analysis Codes for Coaching from Post-Interviews

Power in this study was equated to the knowledge of not only content but also pedagogy and how to tailor effective learning experiences for students in middle school mathematics classrooms. Below is a listing of thematic analysis codes that were generated after grounded theory was employed and emergent themes were seen in post-interviews on coaching. Power and its situated meaning for each code are highlighted below:

<table>
<thead>
<tr>
<th>Code</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Altruistic</td>
<td>Adhering to the idea that education is to make one’s life better. Here power is moving top down in that the coach is working to expand the teacher’s knowledge base (pedagogical and content) and how to adjust instruction to meet the needs of diverse learners. As for a teacher working to make the classroom better for their students in terms of engaging and inviting curriculum by making decisions on what learning from the coach he or she will use in their classroom pedagogy.</td>
</tr>
<tr>
<td>Beyond Coaching</td>
<td>Duties that took on more secretarial like facilitating agenda from office that is not math-specific to filling out paperwork. Quite often these duties pull coaches away from teachers. The district or school requirements exert power over coaches and do not allow them to focus on fostering their coaching relationship with teachers. Often this practice impedes the relationship development between the coach and the teacher.</td>
</tr>
<tr>
<td>Beyond Teaching</td>
<td>Coach provides support beyond just the teaching aspect. Support could be in the form of fostering leadership skills, critical analysis of pedagogical or instructional strategies and promoting better communication among adults and to students or other soft-skills. These skills are important for the teacher to possess in order to determine what learning he or she will take from coaching sessions to implement in their own classrooms. This is an important power sharing action in that the coach is showing the teacher how to establish their own agency in determining what is best for</td>
</tr>
<tr>
<td>Code</td>
<td>Meaning</td>
</tr>
<tr>
<td>--------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td>their classroom. Building this agency in the teacher helps the learning from the coaching sessions become commonplace in the teacher’s pedagogy.</td>
</tr>
<tr>
<td>Coach Availability</td>
<td>Outside agencies vie for the coach’s time and take away the power of the coach to plan for and carry out coaching sessions. The coach is not available to teachers due to scheduling conflicts, too many “other” duties that must be completed or too many teachers to service at one time. This erodes the coaching relationship by not allowing the coach to exert power in planning or facilitating coaching sessions. It also undermines the power of the teacher to determine what, if any, part of the learning from the coaching relationship they want to implement into their classroom pedagogy.</td>
</tr>
<tr>
<td>Collaborative Discussion</td>
<td>Discussion among teachers with or without math coaches that look at best practices, the “how to’s” and watch out fors when implementing strategies, student performance and other topics pertinent to the teaching and learning of mathematics. Discussion with the math coach is the first in the progression of collaborative discussion in which the coach holds most of the power and guides the teacher through how to think about best practice. As time continues and the teacher determines that the coach has established himself or herself as a knowledge other in the sense that the content knowledge is correct, and the pedagogical knowledge is applicable to their classroom, then the teacher decides to internalize this new learning and use it at his or her disposal. When the teacher has decided to internalize the new learning, try out components in his or her own classroom and then take the initiative to talk to other teachers, then deeper level of collaborative discussion develops.</td>
</tr>
<tr>
<td>Communication</td>
<td>Power is initially held with the coach. The coach listens and articulates their own interpretation of what the teacher said he or she needed. Teacher feels they can trust the coach and agree or disagree with the coach’s interpretation. This occurs when there is a relationship between the coach and teacher.</td>
</tr>
<tr>
<td>Co-Teach</td>
<td>Coach teaches a lesson with a teacher in order to help the teacher learn either about an element of pedagogy or help with impacting student performance. Power is shared in that the teacher and coach are both working to instruct</td>
</tr>
<tr>
<td>Code</td>
<td>Meaning</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td>students together. They have co-created the lesson and one is not considered the lead.</td>
</tr>
<tr>
<td>Experience</td>
<td>Teachers exercised their power of determining if a coach had legitimate power, he or she needs years in the classroom before becoming a math coach. If the teacher deemed the coach’s classroom experience acceptable, then they were willing to follow the coach’s suggestions more readily.</td>
</tr>
<tr>
<td>Feedback</td>
<td>Coach holds disciplinary power to provide focused feedback based on observations, conversations or needs assessments.</td>
</tr>
<tr>
<td>Freedom of Choice</td>
<td>Ability of teacher to enact agency on their own professional learning to choose the PDs they feel are pertinent to their classroom content, topics they want to learn about in coaching sessions or discuss in PLCs.</td>
</tr>
<tr>
<td>Immediate Implement</td>
<td>Teachers see resources and activities that are ready-made from either coaches or professional development that do not need anything else done to them. These activities are ready for classroom use as told by the teacher or professional development. Teachers do not have a lot of power. They simply take the activity and implement based on someone else’s directions.</td>
</tr>
<tr>
<td>Know How</td>
<td>Coach’s content and pedagogy knowledge that is useful in supporting and guiding other math teachers. The level of know how that a coach possesses is determined by the teacher’s perception of the coaching relationship, validity of coaching content and professional respect of the coach.</td>
</tr>
<tr>
<td>Lack of Collab (Collaboration)</td>
<td>Outside forces such as time constraints, difficulty in scheduling or unwillingness of teachers to meet and discuss mathematical good practices, research-based instructional strategies, assessment or student learning impedes the cultivation of a coaching relationship.</td>
</tr>
<tr>
<td>Math Over Pedagogy</td>
<td>Some teachers adhere to a personally-adopted belief that college courses, PD or philosophy that places more emphasis on the symbol manipulation and “act of doing math” is more important than learning how to teach mathematics to others. Quite often it is this belief that stifles the coaching relationship in which the teacher will not adopt new instructional practices.</td>
</tr>
<tr>
<td>No Choice</td>
<td>Teachers have no choice in PD due to district regulations or no choice on topics for their coaching sessions.</td>
</tr>
<tr>
<td>Not A Math Coach</td>
<td>Other mentors or coaches such as instructional coaches that are not specifically math knowledgeable. According to</td>
</tr>
<tr>
<td>Code</td>
<td>Meaning</td>
</tr>
<tr>
<td>------------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>teachers in this study, instructional coaches do not have the legitimate power to lead math specific coaching sessions. Therefore, many teachers felt that instructional coaches did not hold the power nor respect they felt necessary for them to follow directives from an instructional coach.</td>
<td></td>
</tr>
<tr>
<td>One Time PD</td>
<td>PD that is a one-time only offering that has no follow-up. Teachers felt powerless in that they had to sit and receive this PD that quite often was not planned based on teacher input or needs.</td>
</tr>
<tr>
<td>Open Pedagogy</td>
<td>Power is located in the instruction itself and allows for students to take ownership of their learning. Math instruction that offers multiple entry points and solution paths. Conceptual understanding is valued more than algorithms. This open pedagogy is the highest form of coaching in the sense that the teacher has turned over power to the students to allow them to chose how they want to represent their solution path and answer.</td>
</tr>
<tr>
<td>PD is N/A</td>
<td>Teacher is powerless in this sense. PD is not applicable due to presented content is not congruent with current grade level taught or it does not meet the professional needs of the teacher.</td>
</tr>
<tr>
<td>Reflection</td>
<td>Teachers enact their agency and power by thinking about their practice and its impact on student performance as evidenced by student work/test scores. Instructional decisions for next steps are based on reflections are with self, math coach or group of math teachers (or any combination of aforementioned).</td>
</tr>
<tr>
<td>Relevance</td>
<td>Teachers exert their power of choice and adaptation of resources or strategies for own classroom guidance either self-guided, with coach’s guidance or with group of math teachers (or any combination of aforementioned).</td>
</tr>
<tr>
<td>Resources</td>
<td>Coach assists the teacher, or the teacher exerts power in the selection of strategies, books, technology or other items that are used in classroom instruction.</td>
</tr>
<tr>
<td>Strategy Alert</td>
<td>Instances of interviews in which teachers shared ideas for specific strategies that they have enacted agency and determined have made an impact on their practice or impact student learning.</td>
</tr>
</tbody>
</table>
| Student Relations| Teachers trying to connect with students to assist them in their learning. Important exercise in that if teachers determine the instructional strategies needed to better teach, then it is imperative that students feel they have a
<table>
<thead>
<tr>
<th>Code</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>relationship with the teacher that provides them the agency to decide and communicate with the teacher the instructional strategies that best fit their needs.</td>
</tr>
<tr>
<td>Support</td>
<td>Coaches meet with teachers to provide guidance, modeling, and feedback. These activities are indicative of the coach holding the power in the relationship because the coach is providing a vision for what’s next to improve their practice.</td>
</tr>
<tr>
<td>Tailoring Help</td>
<td>Power is shared between the coach and teacher. Coach works individually with teacher to provide the service and support that this particular teacher needs (either determined by the coach’s disciplinary power or the teacher’s request to communicate own needs) in order to become a better teacher. (ie. Teacher differentiation)</td>
</tr>
<tr>
<td>Timely</td>
<td>Support given by either coaches or professional development is effective due to nature of when it was given. Timely could mean given when a particular topic fits into the teacher’s curriculum or when feedback is focused and given quickly enough that change can result. It is the teacher’s decision of whether feedback is timely.</td>
</tr>
<tr>
<td>Toward Improvement</td>
<td>Teachers take control of creating a better learning environment for their students by deciding which instructional strategies and new content learning they want to share with their students.</td>
</tr>
<tr>
<td>Workshop Support</td>
<td>Coaching sessions in which the coach provides resources and support for teachers to implement those strategies that are covered in a workshop. The coach is initially seen as the one with the power because he or she possesses the knowledge of how to implement a variety of strategies. Power is then negotiated by the teacher who determines how a strategy would help address the diverse instructional needs of his or her students.</td>
</tr>
</tbody>
</table>
## APPENDIX Q

Timely Mathematical Interventions at a Glance

Share point Site:  [http://www2.research.uky.edu/pimser/p12msotmi/default.aspx](http://www2.research.uky.edu/pimser/p12msotmi/default.aspx)

### Instructional Strategies

<table>
<thead>
<tr>
<th>Date</th>
<th>Activity</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Throughout</td>
<td>Concrete-Representational-Abstract (CRA)</td>
<td>Instructional strategy in which teachers scaffold lessons in which students work with manipulatives such as multi-link cubes, counters, algebra tiles, etc. in order for students to discover patterns. Teachers than push students to draw these representations to cement their understanding of the mathematical topic before working with the abstract or algorithm. (The algorithm is discovered by students versus teacher telling the algorithm.)</td>
</tr>
<tr>
<td>Dec 2014</td>
<td>Stories to Graphs to Movies</td>
<td>Power point activity that had scaffolded questions on graphing real-world scenarios. Activity began with four graphs students had to choose from to describe a scenario. Then students had to draw a graph from a real-world scenario. Finally students watched movie clips and graphed time versus a pre-determined activity.</td>
</tr>
<tr>
<td>Feb 2014, March 2014 and Summer 2014</td>
<td>Number lines</td>
<td>Participants given a FUN number line that includes variety of number types for students to explore ordering, comparing and finding equivalent numbers. (FEB and JULY 2014—SEVERAL FOLDERS OF READY-MADE NUMBERLINE ACTIVITIES)</td>
</tr>
<tr>
<td>March 2014 and Summer 2014</td>
<td>Open and Closed Number Lines with Double Number Lines</td>
<td>Use of Engage NY curriculum to demonstrate how to teach mathematical operations by using the number line.</td>
</tr>
</tbody>
</table>
Sept and Oct 2014 and June 2015 | Silent Teaching | Strategy in which teacher and students do not talk. It relies on a math concept in which a repeated pattern that students can make generalizations over in order to learn the concept. Examples highlighted were number line, distributive property and Law of Exponents. Participants also created their own.

### Instructional Strategies

<table>
<thead>
<tr>
<th>Date</th>
<th>Activity</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>June, July and Aug 2015</td>
<td>Algebra Tiles</td>
<td>Foam manipulatives used to concretely represent integer operations, fractional representations/operations, algebraic concepts such as distributive property/equations/factoring</td>
</tr>
<tr>
<td>Aug - Oct 2015</td>
<td>3 Types of Effective Questions (Generalization, Reversibility, and Flexibility)</td>
<td>Creating questions that are open-ended leads to increased mathematical discourse.</td>
</tr>
</tbody>
</table>
| Throughout          | Proportional Labs and Data Gathering Activities | A listing of labs: (Feb 2016) All Knotted Up—linear investigation with rope; Cleaning Power of Borax—non-linear investigation with detergent and temperature of water  
(Oct 2015) Picture It on Your I Phone—data collection of taking a picture of a person holding a ruler to determine their height; Indirect Measurement Using Mirrors and Shadows—determine height of various objects; How Many Noses in Your Arm?—determine length of Statue of Liberty’s arm based on lengths of your nose. |
Aug 2014 | Pattern Blocks | Foam manipulatives (you have the dies for these) that were used to instruct on the distributive property (Spread the Pattern Blocks) and to derive equations (String of Pattern Blocks).

Sept and Oct 2014 | Multi-Link Cubes | Labs in which students build 3-D figures and then analyze the rate of change and y-intercept along with filling out NAGS Link sheets.

Sept -Dec 2015 | Math Stations | Use of a series of mathematical problems and scenarios that students more around to solve. TMI used activities and tasks from FALs and Scale City.

<table>
<thead>
<tr>
<th>Date</th>
<th>Activity</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oct 2014</td>
<td>Link Sheets with Extended Table</td>
<td>Instructional strategy in which the typical t-chart that is used by students to derive algebraic equations is replaced with a middle column that allows for students to write down and analyze patterns they see between the x and y columns.</td>
</tr>
<tr>
<td>Throughout</td>
<td>Multiple Representations (NAGS Rule or Link Sheet)</td>
<td>Instructional strategy where students are taught and encouraged to represent their solutions in multiple ways. (N-numbers in tables, A-algebraic rule, G-graph and S-situation)</td>
</tr>
<tr>
<td>Oct 2014</td>
<td>Flyswatter</td>
<td>Activity for recall and automaticity in which a game board with perfect squares/square roots; perfect cubes/cube roots and benchmark fractions/decimals and percents are under a document camera. Students use flyswatters to identify the answers the fastest.</td>
</tr>
<tr>
<td>Dec 2015</td>
<td>Tape Diagrams</td>
<td>Representations used to show proportional relationships between quantities.</td>
</tr>
<tr>
<td>Sept 2015</td>
<td>Table Top</td>
<td>Instructional strategy in which a large piece of poster paper is used</td>
</tr>
</tbody>
</table>
by a group of students who were given an open math task. Students first work on their own by showing work on the corner of the paper, then a group solution is derived and written in the middle of the paper.

<table>
<thead>
<tr>
<th>Date</th>
<th>Activity</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>March 2016</td>
<td>Rubber Band Dilation Activity</td>
<td>Adaptation of activity from It’s All Relative flipbook. Students use rubber bands, pencil and paper to learn about scale factor and its effects on a pre-image.</td>
</tr>
<tr>
<td>June-July 2015</td>
<td>Instructional Intervention Sequence (IIS)</td>
<td>All participants created a series of at least three strategies that are used to help struggling learners with a particular topic. IIS can be used in RTI time. These are housed in Share point.</td>
</tr>
</tbody>
</table>

### Games

<table>
<thead>
<tr>
<th>Date</th>
<th>Activity</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aug 2015</td>
<td>Factor Find</td>
<td>Roll a die to get a factor. Then choose a card from a rectangular array of fraction cards that has a numerator and denominator that shares the factor that was rolled.</td>
</tr>
<tr>
<td>Aug 2015</td>
<td>Fraction Rummy</td>
<td>Game played like Rummy but uses three equivalent fractions (if using fraction cards) or 3 equivalent representations (if you are using fraction/decimal/percent cards)</td>
</tr>
<tr>
<td>Oct 2015</td>
<td>Ratio Game</td>
<td>Game uses a deck of playing cards and a deck of fraction cards. Each player given 5 playing cards. One fraction card is turned over which is the ratio that the students try to make in their hand of 5 cards.</td>
</tr>
<tr>
<td>June 2015</td>
<td>Linear Match</td>
<td>Students group equivalent graphs, equations and tables together to make groups. Can be used as a Memory game as well.</td>
</tr>
<tr>
<td>June 2015</td>
<td>Expression War</td>
<td>Game that uses dice and expression cards in which students substitute</td>
</tr>
</tbody>
</table>
numbers in expressions and try to get the highest answer.

<table>
<thead>
<tr>
<th>Date</th>
<th>Activity</th>
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</tr>
</thead>
<tbody>
<tr>
<td>June 2015</td>
<td>Equivalent Spoons</td>
<td>Game is played like spoons but uses fraction/decimal/percent cards. Students get 3 equivalent representations before initially picking up a spoon.</td>
</tr>
<tr>
<td>July 2015</td>
<td>Integer Capture</td>
<td>Game uses integer cards and Integer Capture boards. Students create problems by using any basic operation or combination of operations to get a number on the Integer Capture board. Winner is one that gets four in a row.</td>
</tr>
<tr>
<td>July 2015</td>
<td>Kaboom</td>
<td>Class game in which an equation is given to the group. Fastest one to solve and show work will get the number of points that is equivalent to the answer they gave.</td>
</tr>
</tbody>
</table>

**Math Tools: By Harvey Silver**

<table>
<thead>
<tr>
<th>Date</th>
<th>Activity</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dec 2014</td>
<td>Fist Lists/Spiders (p. 8-10)</td>
<td>A vocabulary or information gathering tool in which students list attributes of a topic (for fist list 5 attributes and spider 8 attributes)</td>
</tr>
<tr>
<td>Aug 2015 and Feb 2016</td>
<td>Vocabulary Knowledge Rating (p. 38-40)</td>
<td>Self-reflection tool in which students rate how familiar they are with particular vocabulary words or concepts in a unit.</td>
</tr>
<tr>
<td>Aug 2014 and March 2015</td>
<td>Memory Box (p. 25-27)</td>
<td>Students brainstorm all the information they know about a given mathematical topic and write it down.</td>
</tr>
<tr>
<td>Aug 2014</td>
<td>Most Valuable Point (MVP) (p. 30-31)</td>
<td>Students think about what they know about a particular mathematical topic and decide</td>
</tr>
</tbody>
</table>
which is the most important piece of information they know. Then students write about why that piece of information is the most important point they need to know. (This strategy is often completed with Memory Box)

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Feb 2016</td>
<td>3-Way Tie (p. 95-96)</td>
<td>Vocabulary strategy in which a student chooses three vocabulary words and writes how the three are connected. This strategy was also used as a NAGS Rule sheet.</td>
</tr>
<tr>
<td>Sept 2015</td>
<td>Linear Lingo (p. 120)</td>
<td>Group and label activity in which students are given vocabulary or mathematical problems and they have to group them according to common attributes.</td>
</tr>
<tr>
<td>June 2015</td>
<td>Comprehension Menu (p. 208-211)</td>
<td>A series of four tasks or questions on a particular topic that address Silver’s four learning styles.</td>
</tr>
<tr>
<td>July 2015</td>
<td>I Know What I Know (p. 162-163)</td>
<td>Reflection tool in which students will in blanks to describe what they have learned in the day’s lesson.</td>
</tr>
<tr>
<td>July 2015</td>
<td>Metaphorical Duels (p. 135-136)</td>
<td>Comparing mathematical topics or processes to other objects or scenarios.</td>
</tr>
</tbody>
</table>

**Math Tools: By Harvey Silver**

<table>
<thead>
<tr>
<th>Date</th>
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<tbody>
<tr>
<td>July 2015</td>
<td>Range Finder (p. 181-183)</td>
<td>A series of math tasks that vary in difficulty are given to students which chose the level of problems they feel comfortable solving.</td>
</tr>
<tr>
<td>July 2015</td>
<td>Show Me (p. 82-84)</td>
<td>Strategy in which students have to identify equivalent problems/scenarios, generate lists of problems/scenarios that are equivalent or illustrate a concept.</td>
</tr>
<tr>
<td>July 2015</td>
<td>Yes But Why (p. 101-103)</td>
<td>Solutions to math tasks are shared and the students must write why the solutions are correct.</td>
</tr>
<tr>
<td>Summer 2016</td>
<td>Boggle (p. 169-170)</td>
<td>Review strategy in which students first brainstorm all they know about a topic. After brainstorming, students are paired up and share</td>
</tr>
</tbody>
</table>
If a student has an answer the other does not have, then he/she gets a point. The student that does not have the answer adds it to their list.

### Technology and Websites

<table>
<thead>
<tr>
<th>Date</th>
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</thead>
<tbody>
<tr>
<td>Dec 2014</td>
<td>Formative Assessment Lessons</td>
<td>Lessons from <a href="http://map.mathshell.org/lessons.php">http://map.mathshell.org/lessons.php</a> that highlights a variety of math topics for middle and high school. FALS used in TMI included: Proportional Reasoning, Interpreting Distance/Time Graphs, Functions &amp; Everyday Situations, Solving Proportional Problems</td>
</tr>
<tr>
<td>March 2014</td>
<td>Engage NY</td>
<td>Lessons from <a href="https://www.engageny.org/">https://www.engageny.org/</a> highlighted open number lines and double number lines</td>
</tr>
</tbody>
</table>

### Technology and Websites

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<thead>
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<th>Description</th>
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<tbody>
<tr>
<td>Oct and Dec 2015</td>
<td>Dan Meyer’s 3-Act Lessons</td>
<td>Website that has lessons that include video clips and a lesson format in which students examine a scenario, make predictions and then determine a solution based on information and estimation. TMI used Rope Jumper and Penny Circle. Google: “Dan Meyer 3-Act Lessons” then click on “Dan Meyer’s 3 Act Math Tasks—Google Sheets”</td>
</tr>
<tr>
<td>Throughout</td>
<td>DESMOS and Teacher DESMOS</td>
<td>Free on-line graphing calculator found at <a href="https://www.desmos.com/">https://www.desmos.com/</a> A teacher website has premade activities in which students log in to complete</td>
</tr>
</tbody>
</table>
mathematical investigations is found at: https://teacher.desmos.com/
TMI completed Penny Circle and Central Park.

Feb 2016 | Graphing Stories Website | The website: www.graphingstories.com includes video clips of a variety of activities and reproducible coordinate planes that students use to graph the situation based on two variables.

March 2015 | Georgia Department of Education | Some TMI activities have come from this website which houses many activities and curriculum ideas: https://www.georgiastandards.org/Georgia-Standards/Pages/default.aspx

Sept 2015 | Bad Date Video | This funny clip demonstrates how ratios are derived and reported. Clip found at http://mathsnacks.com/baddate-en.html

June 2015 | Kahoot! | Interactive game site in which teachers can create games or use pre-made games and students answer using their phones. Website: https://getkahoot.com/

March 2016 | KET’s Scale City | Interactive curriculum on proportional reasoning. TMI highlighted the Miniature Land and Sky-Vue Drive In. Website: https://www.ket.org/scalecity/

### Educational Research

<table>
<thead>
<tr>
<th>Date</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Aug 2014</td>
<td>John Hattie’s Research on High Impact Instruction</td>
<td>Listed the top 10 strategies that are often used in schools and their effect size.</td>
</tr>
<tr>
<td>Aug 2014 and Throughout Project</td>
<td>Shirley Clarke’s Learning Powers</td>
<td>List of attributes students need to demonstrate for successful learning. Include the following: Concentrate, Don’t Give Up, Be Cooperative, Be Curious, Have a Go, Use Your Imagination, Keep Improving, and Enjoy Learning</td>
</tr>
<tr>
<td>Feb 2014 and Throughout Project</td>
<td>Growth vs Fixed Mindset</td>
<td>Work from Carol Dweck that emphasizes all students can learn mathematics.</td>
</tr>
<tr>
<td>Timeframe</td>
<td>Resource Title</td>
<td>Description</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>-----------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Aug – Oct 2014 and March 2016</td>
<td>Talk Partners</td>
<td>Work from Shirley Clarke that emphasizes students being randomly assigned to a partner for class instruction. Randomization of calling on students and higher order open questioning is also emphasized in Clarke’s research.</td>
</tr>
<tr>
<td>Aug 2015 - June 2016</td>
<td>Marian Small’s Proportional Reasoning Across Grade and Math Strands, K-8</td>
<td>Book that highlights the vertical progression of proportional reasoning throughout the grade levels. Each section has activities and examples of rigorous open-ended questions (in 3 styles we learned) to pose in your classroom.</td>
</tr>
<tr>
<td>Dec 2015 and March 2016</td>
<td>It’s All Relative: Flip chart on proportional reasoning</td>
<td>Compilation of a variety of ready-made activities for proportionality instruction. Each activity has a information on how it addresses the Standards and how to combat student commonly held misconceptions.</td>
</tr>
<tr>
<td>Summer 2016</td>
<td>Total Participation Techniques</td>
<td>Compilation of a variety of ready-made strategies that can be used to increase student engagement and effective discourse in the classroom.</td>
</tr>
</tbody>
</table>
APPENDIX R

Timely Mathematical Interventions at a Glance…ADDENDUM

Share point Site:  http://www2.research.uky.edu/pimser/p12msotmi/default.aspx

Instructional Strategies

<table>
<thead>
<tr>
<th>Date</th>
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</tr>
</thead>
<tbody>
<tr>
<td>June 2016</td>
<td>Total Participation Techniques (TPT)</td>
<td>Resource given to participants that has a variety of strategies for student engagement in class. Good examples of how to effectively use formative assessment in your class.</td>
</tr>
<tr>
<td>June 2016</td>
<td>What Math Lurks in the Shadows?</td>
<td>An activity adapted from Scale City’s Sky-Vue Drive-In and April 2016 Mathematics Teaching in the Middle School “It’s a Bird, It’s a Plane, It’s a Dilated Superhero” that examines the inverse proportional relationship between the height of a shadow and the distance the object is from the light source.</td>
</tr>
<tr>
<td>June 2016</td>
<td>Penny Bridge</td>
<td>Data collection activity in which students place pennies on paper bridges of varying lengths. Tables and graphs were constructed based on the length of the bridge and the number of pennies held.</td>
</tr>
<tr>
<td>June 2016</td>
<td>Spaghetti Bridge</td>
<td>Data collection activity in which students suspends a small cup from strands of spaghetti and places pennies in the cup. Tables and graphs were constructed based on the number of strands of spaghetti and the number of pennies held.</td>
</tr>
<tr>
<td>June 2016</td>
<td>Globe-Trotting Activity</td>
<td>Students collect data by throwing inflatable globes to music. When the music stops, students then determine if their thumbs are on top of land or water. After several rounds of data collection, the participants determine the percentage of land and water on Earth and compare to the actual percentages.</td>
</tr>
</tbody>
</table>
June 2016 | Teach-Learn Station Model | Model of station teaching in which students move between staying at a station and teaching another student and then moving to a new station to become a learner. Share point has a set of cards that helps teachers to group the students for this type of station teaching.

### Instructional Strategies

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>June 2016</td>
<td>STEM Stations</td>
<td>Stations based on understanding proportionality that focused on genetics and chemical reactions.</td>
</tr>
</tbody>
</table>

### Games

<table>
<thead>
<tr>
<th>Date</th>
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</tr>
</thead>
<tbody>
<tr>
<td>June 2016</td>
<td>4 in a Row</td>
<td>Game in which students use spinner or dice to answer questions and cover with bingo chips. Winner is the one that can cover 4 in a row vertically, horizontally or diagonally. Content can vary for this game but ratios were highlighted on this day.</td>
</tr>
<tr>
<td>June 2016</td>
<td>Bump</td>
<td>Game in which students are given 8 bingo chips and they must get all 8 on the board in order to win. Students can bump each other if they have the same answer.</td>
</tr>
</tbody>
</table>

### Math Tools: By Harvey Silver

<table>
<thead>
<tr>
<th>Date</th>
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</tr>
</thead>
<tbody>
<tr>
<td>June 2016</td>
<td>Top Hat organizer</td>
<td>A visual organizer used to help students to describe the similarities and differences between two concepts. This month we compared and contrasted direct and inverse proportions.</td>
</tr>
</tbody>
</table>
APPENDIX S

NAGS LINK SHEET

Pattern
Draw the next two representations:

<table>
<thead>
<tr>
<th></th>
<th>Mathematical Calculations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<tr>
<td>2</td>
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<td>3</td>
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<td>4</td>
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<td>5</td>
<td></td>
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<tr>
<td>10</td>
<td></td>
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<tr>
<td>25</td>
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<td>n</td>
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</tbody>
</table>

Fill out the table below based on your block pattern.

Write a description of how you built using your pattern.

This relationship a direct variation (proportional)?

How do you know based on a graph? a table? an equation?

Write an equation for this relationship.

<p>| | | | | | | | |</p>
<table>
<thead>
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</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
</tbody>
</table>
REFERENCES


Kentucky Department of Education. (2012). *A guide to Kentucky systems of intervention*. Retrieved from:


Vita

Jamie-Marie Louise (Wilder) Miller

Education

Masters of Arts in Education, May 2005
Concentration: School Counseling and Individualized Intellectual Assessment
Eastern Kentucky University, Richmond, Kentucky

Bachelor of Science, May 1999
Major: Middle School Education with emphasis in Mathematics and Social Studies
Minors: History and Psychology

Professional Experience

Part-time College Teaching

Transylvania University, Lexington, Kentucky, Fall 2016 and Spring 2017

P-12 Teaching

Instructional Coach, 2016-Present
Lincoln County Middle School, Stanford, Kentucky

Mathematics Consultant (part-time), 2007-2009
Lincoln County Middle School, Stanford, Kentucky

Mathematics Teacher, 1999-2014
Lincoln County High School, Stanford, Kentucky, 1999-2003
Lincoln County Middle School, Stanford, Kentucky, 2003-2014

Supervision

University Supervisor for Pre-Service Teachers, Fall 2015 and Spring 2016
University of Kentucky, Lexington, Kentucky

KTIP Resource Teacher, 2010-2011
Lincoln County Middle School, Stanford, Kentucky

Awards

Mathematics Education Service & Achievement Award (MESA Award), October 2009
Kentucky Council of Teachers of Mathematics (KCTM)
Publications


Organizations

National Education Association
Kentucky Education Association
National Council for Teachers of Mathematics
Kentucky Council for Teachers of Mathematics
Association for Supervision and Curriculum Development