

ABSTRACT

LEE, CARRIE WILKERSON. *Orchestrating Mathematical Discourse: Affordances and Hindrances for Elementary Novice Teachers*. (Under the direction of Temple Walkowiak and John Nietfeld).

The purpose of this study was to examine the mathematical discourse within novice elementary teachers' classrooms. More specifically, this study employed a sequential, explanatory mixed methods design to first quantitatively analyze the relationship between teachers' discourse practices and teacher attributes and school context. Next, a qualitative examination of the classroom discussions was conducted to investigate patterns with teachers' discourse moves.

In the quantitative phase a series of multi-level, means-as-outcomes regression analyses were conducted with a sample of 119 novice elementary teachers to examine how teacher attributes and school contextual variables accounted for variance in the level of mathematical discourse community and the level of student explanation and justification. School contextual factors, including socioeconomic status and teacher support, and teachers' mathematical knowledge for teaching and beliefs were predictive of different dimensions of mathematical discourse.

Based on the quantitative findings, fourteen teachers were selected for the qualitative phase and their classroom discussions were coded to reveal patterns in the teachers' orchestration of discussions. The analysis of teacher moves showed that teachers with higher levels of mathematical knowledge for teaching used more open-ended questioning and prompted more student contributions. Also, the analysis highlighted the abundance of literal questioning for all teachers in the subsample.

Findings from the quantitative and qualitative phase corroborate the influence of teachers' mathematical knowledge for teaching on the nature of discourse within mathematics lessons, and present other teacher attributes and school contextual factors that also relate. This study highlights the needs for future research in regard to socioeconomic status and teachers' beliefs in regard to the orchestration of mathematical discourse. Implications for teacher educators, including per-service preparation and professional development, are outlined.

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Orchestrating Mathematical Discourse:
Affordances and Hindrances for Novice Elementary Teachers

by
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DEDICATION

This work is dedicated to Henry. With every cry, giggle, and curious look, Henry has forced perspective throughout this process. First and foremost, I strive to be an imperfect person that shows him grace and love. Secondly, I toil to educate future teachers so that mathematics can be empowering for Henry and all other children.

BIOGRAPHY

Carrie Lee is a native of North Carolina where she currently lives. She grew up in a loving family that held education in high regard. Due to the value for education and her parents' dedication to provide resources, Carrie was the valedictorian of her high school class and was the first in her family to graduate from a four-year institution.

Carrie attended Duke University, and initially pursued a biology degree with plans to study pediatrics in medical school. However, as a sophomore, Carrie enrolled in an *Introduction to Teaching* course and her path was diverted. The service learning component of the course allowed for her to interact with elementary students and the coursework forced her to confront educational issues to which she was ignorant. The impact of teachers on students' lives became an irreconcilable force that overpowered past inklings and forged a new passion for education. After much prayer, and heated arguments with her parents, Carrie declared psychology as her major with a dual certification in elementary education.

Upon graduation in 2006 Carrie accepted a fifth grade teaching position in Durham, NC at the school in which she completed her student-teaching internship. After two years in Durham, as result of moving, Carrie taught an additional four years in Clayton, NC.

As a former fifth grade teacher, Carrie was troubled by the number of students that came into her classroom with a fear and hatred of mathematics. During their time with her, Carrie worked to transform mathematics from a set of procedures to be memorized to a tool that helps make sense of the world around us. Carrie's desire to restore mathematics to its rightful place for elementary children is the motivating force behind her journey as a mathematics teacher educator. By creating opportunities for pre-service and in-service

teachers to authentically interact with the mathematics, Carrie feels she can empower them to change the field for the better. As a teacher educator she strives to construct learning experiences inside and outside of the formal college classroom that prepare effective teachers by promoting a growth mindset, increasing mathematical knowledge for teaching, and modeling a learning environment that positions students as capable thinkers and doers.

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The foundation of any building determines how the subsequent phases of the project will be supported and in the end how they will endure against the elements. My foundation is the Lord, Jesus Christ, and by analyzing the phases of my life I can see, vividly, how He has directed the construction of experiences and blessings that have led to this moment in time. For His guidance and unfailing love I am eternally grateful and forever motivated to serve. He has allowed me to find purpose in serving others through the field of education, and I will continue to serve with a passion that is fueled by Him. Get ready.

As a part of my construction, God has built strong support beams in the form of an amazing family that has pushed me to live out my purpose. Thank you Mom and Dad for your unwavering love and support. You preached the value of education and the love of Christ and taught me not to take myself too seriously. You always treated others as more important than yourselves, and that is one trait I attempt to imitate daily. Thank you, Katie, for always offering words of encouragement and being so strong in your faith. Even though you are younger, I look up to you in so many ways.

In addition to sturdy support beams, God gave me an amazing husband to share in the journey. Kevin, in keeping with the building analogy (that one is for you), I cannot narrow down what part of the building process you would be. You are the electrical wiring because you energize me to keep dreaming and striving for my goals. You are the roof because you provide shelter and protection for our family through your reassurances and strong presence. You are the insulation because you keep us cool with your endless humor and simultaneously ensure warmth with your sincere compassion. All of these amazing traits are part of the

reason I was able complete this process; you carried our family when I had to slip away to write or study. Lastly, you are my skylight because you constantly show me the Son through your actions and sacrifices. I. love. you.

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Lastly, I am in awe of the untouchable committee that I was honored to learn from through my dissertation process. Margareta, Valerie, John, and Temple, thank you for your willingness to listen and mentor. I will sing your praises forever.

Margereta. Thank you for providing me with numerous opportunities to present and collaborate on manuscripts. Your encouragement helped me build my confidence and feel safe when participating in a new world.

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Chapter One: Introduction

Due to international comparisons (OECD, 2014) and global competition in science and mathematics-related fields, mathematics education in the United States has undergone scrutiny in recent years. Students in the United States have been criticized as lacking the skills needed to be effective problem solvers and communicators (Ma, 1999). These findings are often attributed to the emphasis on the correct answer in U.S. mathematics classrooms, without adequate attention to critical thinking deemed relevant in the workplace and professional circles (Stigler & Hiebert, 2004; Franke, Kazemi, & Battey, 2007). That is, American students are taught how to follow a procedure and get an answer, but they are not equipped with conceptual understanding or the skills to justify or explain their solutions (Stigler & Hiebert, 1999). Elementary experiences lay the foundation for conceptual understanding in mathematics, and therefore ensuring high-quality instruction in elementary mathematics classrooms is seen as the first step to promoting success (National Research Council, 2001).

As a community, mathematics educators have identified specific standards-based practices, also referred to as reform-based practices, that emphasize conceptual understanding and should guide teachers' instruction and students' thinking (NCTM, 1989, 2000; CCSSM, 2010). These standards-based practices (see Table 1.1), including problem solving and justification of ideas, have been well documented and endorsed for over three decades of reform and have proven to benefit students (Ross, McDougall, & Hogaboam-Gray, 2002; Fuson, Carroll, & Drucek, 2000; Riordan & Noyce, 2001; Senk & Thompson, 2003). However, successful implementation of these standards-based practices has not been

the norm in U.S. classrooms (Ross, McDougall, Hogaboam-Gray, & LeSage, 2003) due to teachers’ superficial accommodation of reform efforts (Kazemi & Stipek, 2001).

Table 1.1
Standards-based Practices

NCTM Process Standards (2000)	Standards for Mathematical Practice (CCSSM, 2010)	Mathematics Teaching Practices (NCTM, 2014)
Communication	Construct viable arguments and critique the reasoning of others	Elicit and use evidence of student thinking. Pose purposeful questions.
Problem Solving	Make sense of problems and persevere in solving them	Establish mathematics goals to focus learning.
Reasoning and Proof	Reason abstractly and quantitatively	Support productive struggle in learning mathematics.
Connections	Attend to precision	Implement tasks that promote reasoning and problem solving
	Look for and express regularity in repeated reasoning	Build procedural fluency from conceptual understanding.
	Look for and make use of structure	
Representations	Model with mathematics	Use and connect mathematical representations.
	Use appropriate tools strategically	Use and connect mathematical representations.
	Use appropriate tools strategically	

The culprit to substantial reform is often cited as teachers’ deep rooted past experiences with more “traditional” models of teaching that emphasize transmission of procedural understanding (Feiman-Nemser & Buchmann, 1985; Stevenson & Stigler, 1994).

These experiences often overpower teachers' more recent discovery of standards-based practices in formal teacher preparation programs. Through coursework and clinical experiences, pre-service teachers are typically trained in standards-based practices in their teacher preparation programs, and these programs could be one of the most formidable forms of professional development a teacher will engage in during their careers (Association of Mathematics Educators, 2010).

One standards-based practice and the focus of this study is effective communication of mathematical ideas, including explanation and justification (NCTM, 1989, 2000, 2014; CCSSM, 2010). This communication, generally referred to as discourse within the field, is not a simple phenomenon to create within a classroom, and it requires that teachers and students co-create a community for mathematical discussions to occur. High-quality discourse both develops students' abilities to participate in the construction of knowledge and cultivates communication skills that reach beyond the classroom. However, research has indicated that this type of discourse is not happening in mainstream classrooms (Michaels & O'Connor, 2015).

We might think of practicing teachers belonging to one of two categories, novice teachers emerging from teacher preparation programs in recent years (three years or less) and more experienced teachers that have been in the field much longer. This study focuses on the former group and considers whether current teacher preparation prepares these novice teachers for this demanding change in classroom culture. Are novice teachers, emerging from teacher preparation programs, able to actualize high-quality mathematical discourse in their classrooms? Research is needed to better understand the factors that promote and constrain

effective use of discourse practices early in a teacher’s career, beginning with an examination of how novice teachers are implementing discourse practices in their mathematics lessons.

Figure 1.0 highlights the focus of the current study on the novice teacher sample. Examining practices during the induction years will provide insight into the bridge and possible disconnects between formal preparation and membership in the teaching profession.

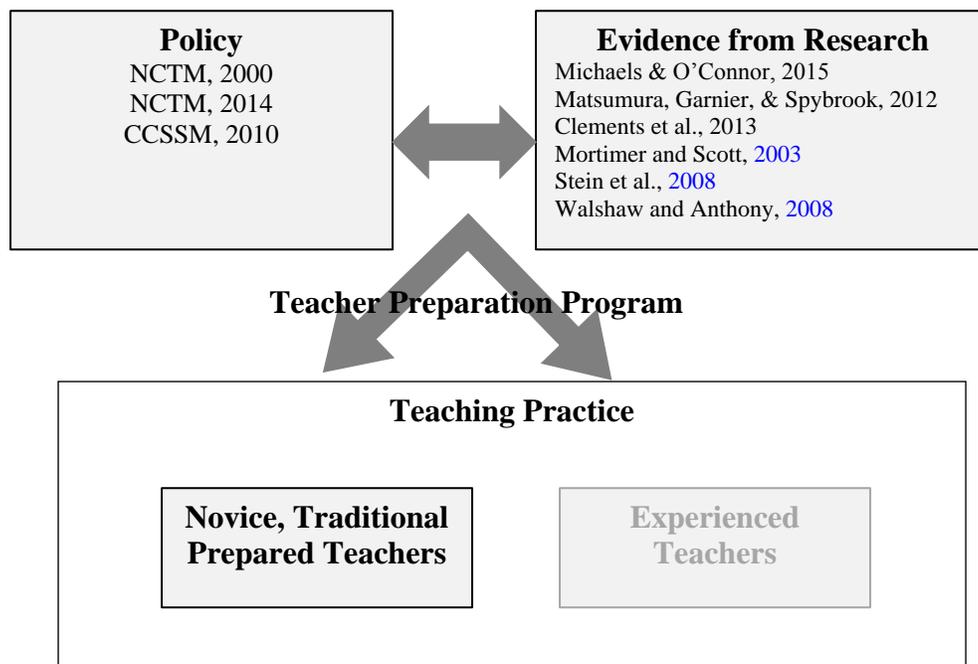


Figure 1.1 *Binding of current study to novice teachers.*

Purpose of Study

The purpose of this study is to investigate the mathematical discourse in novice (second-year) elementary teachers’ classrooms and the factors that promote and constrain effective use of discourse. A sequential, explanatory mixed methods design will be employed to accomplish the purposes of this study. The first quantitative phase of the study will

determine what factors (i.e., knowledge, beliefs, and context) account for variance in the quality of mathematical discourse in novice teachers' classrooms. Descriptive and inferential statistics will be provided from a multi-level model analysis. These results will be used to select participants for the second, qualitative phase which will further explain the differences in teacher groups by comparing and contrasting the specific moves teachers make during classroom discussions. The researcher, through systematic coding, will provide visual, infographic representations of teachers' utterances within classroom discussions as well as examples of the discourse.

Significance

This study goes beyond current research on standards-based mathematics instruction by analyzing multiple dimensions of the teacher, including knowledge and beliefs, as well as contextual factors. Current research has examined the relationship between knowledge and practice (Hill et al., 2008; Hill, Umland, Litke, & Kapitula, 2012), but these studies have utilized small sample sizes and have not focused on classroom discourse. Furthermore, this study specifically analyzes the mathematical discourse within novice teachers' classrooms to shed light on this particular population early in their careers. This work will apply a standards-based observational tool to measure the instruction of novice teachers, at a relatively larger scale, and inform future research in regards to the novice population and use of observational content-specific measures.

Beyond the examination of knowledge, most work around teacher beliefs in mathematics education has utilized small sample sizes to allow for rich exploration through qualitative processes (e.g., Raymond, 1997) or has omitted the link to practice (Philip, 2007). Fives and

Buehl (2012) call for research that includes individual and contextual factors when studying beliefs, and this study addresses this gap by measuring epistemological and efficacy beliefs, along with knowledge, to examine the joint relationship to practice. Another contextual factor that this study examines is the perceived level of support teachers report from their school administration and coworkers, specifically in regards to mathematics instruction. This perception of support provides more insight into the mathematics community at the school than has been addressed in previous research (Fives & Buehl, 2005).

Also, by purposefully focusing on novice teachers' instructional practices, this study provides insight into an underrepresented population in the literature. Most research on instructional practices has utilized convenience samples without direct interest in experience level or have sampled from more experienced teachers due to accessibility. Findings from this study will provide implications for induction and professional development as well as for teacher preparation programs.

Lastly, the observational measures used within this study extend research on content or skill-specific measures of practice. The Mathematics Scan, M-Scan (Berry et al., 2010), is used to measure standards-based mathematics teaching practices, specifically mathematical discourse in this study, and the Analyzing Teacher Moves (ATM) Guide (Correnti et al., 2015) is used to examine how teachers orchestrate classroom discourse at a finer-grain level.

Definition of Terms

1. Pre-service teacher: An individual in a teacher preparation program at a college or university.

2. Novice teacher: An individual who is in their first three years of classroom teaching. In the methodology and findings of this study, “novice” will be used to describe the participants who were all in their second year of teaching.
3. Standards-based mathematics teaching practices: Teaching that attempts to meaningfully implement the mathematics teaching practices advocated by NCTM (2007; 2014) and the Standards for Mathematical Practice in the Common Core State Standards (CCSSM, 2010). Standards-based teaching is also referred to as reform-based teaching.
4. Sociomathematical norms: The norms particular to mathematics that a classroom community creates to define how they will justify their mathematical work (Yackel & Cobb, 1997).
5. Discourse practices: Communication of mathematical ideas, including the explanation, clarification, and justification of those ideas (NCTM, 2000; 2007).
 - a. Mathematical Discourse Community: The classroom environment, including inferred sociomathematical norms, in which students will engage in discourse practices (Borko, et al., 2005; Walkowiak et al., 2014).
 - b. Explanation and Justification: Discourse practices that students engage in to share solution strategies and support their reasoning for doing so. The teacher often probes students by asking “how” and “why” questions (Borko, et al., 2005; Walkowiak et al., 2014).
6. Mathematical knowledge for teaching (MKT): The specialized type of knowledge that teachers need to effectively teach. This knowledge is comprised of content

- knowledge of the topic along with an understanding of multiple solution methods and methods for addressing student misconceptions (Ball, Thames, & Phelps, 2008).
7. Teachers' beliefs about teaching and learning of mathematics (TB): These are beliefs that are epistemological in nature and refer to what the teacher believes is mathematics and how the teacher believes it should be taught and learned (Philipp, 2002).
 8. Personal Mathematics Teaching Efficacy (PMTE): A teacher's beliefs about how effectively he/she can teach mathematics (Enoch, Smith & Huinker, 2000).
 9. Context: Any aspect of a person's surroundings that impacts their choices and thoughts.
 - a. Teacher's perception of school support for mathematics (TPSS): A teacher's self-reported perceptions of how the school setting is constructed to support the effective teaching of mathematics.
 - b. Socioeconomic status (SES): A measure of an individual's or family's economic and social position in relation to others, based on income, education, and occupation. In this study SES of a school is operationalized by a measure of the percentage of students within the school that are eligible for free and/or reduced priced lunch (FRPL). The eligibility for FRPL is based on a family's income in comparison to the national poverty threshold (USDA, 2015).

Organization of Study

In Chapter 1, the current study was introduced, its purpose and significance were explained, and key terms were defined. Chapter 2 begins with a justification of the theoretical framework underpinning the study. Next, a review of literature on mathematics discourse, teacher attributes and school context is presented. At the conclusion of Chapter 2, the research questions are outlined. Due to the integral nature of the quantitative results for the qualitative methodology, the quantitative phase is presented prior to the qualitative phase. An explanation of the quantitative methods is presented in Chapter 3, with results to the quantitative phase outlined in Chapter 4. Qualitative methodology is described in Chapter 5 followed by the qualitative findings in Chapter 6. The study is concluded with an integrated discussion of the findings in Chapter 7; including delineation of limitations and future research.

Chapter 2: Review of the Literature

This review of the literature will begin by positioning the study within a situative framework. Next, a comprehensive examination of mathematical discourse will be presented including a summary of work on sociomathematical norms, specific discourse practices, and tools used to study discourse. Subsequently, the review will narrow to consider the individual context of the teacher, and in particular the novice teacher. Research on teachers' knowledge, epistemological beliefs, and efficacy will be synthesized to further delineate how these teacher attributes have been approached in the field. Lastly, the influence of school context will be addressed.

Theoretical Framework

Effective discourse, and learning for that matter, is a complex phenomenon; the teacher and students bring their own experiences and expectations into the classroom that influence their participation in their interactions with others. This study employs a situative approach to learning, in which learning is conceptualized as a social endeavor (Lave & Wenger, 1991; Cobb & Yackel, 1996). Situative theory focuses not only on how individuals influence one another, but also on how the cultural beliefs and expectations of a group impact how an individual acts and learns (Lave & Wenger, 1991). This study applies this theoretical framework to the analysis of teachers and students and how they interact within the classroom. Within the classroom learning community, students are learning as they engage in and with the environment and fellow learners, including the teacher. This environment is to some degree controlled by the actions and presupposed beliefs of the teacher. The teacher

guides the establishment of classroom expectations and is like the “old timer” or the “more knowledgeable other” in the classroom community (Lave & Wenger, 1991).

However, by applying a situative lens, one must also acknowledge that the classroom community is an internal creation of a larger community of practice that includes the teachers within the school culture. When considering the teacher, we must remember that as teachers prepare and enter the field, they are enculturated into the role of teacher by social norms and actions presented by fellow colleagues and the structure of the school setting (Brown, Collins, & Duguid, 1989). It is through participation in these communities of practice, what Lave and Wenger (1991) coin as *legitimate peripheral participation*, that novice teachers develop skills and knowledge to successfully impact student learning. Novice teachers engage in authentic or “legitimate” participation in the profession of teaching; however, they remain a more peripheral member as they learn the ins and outs of their school setting. As they begin to be more acquainted with their school context they begin to move from the periphery to a more centralized form of engagement with the school community. At the point of more centralized engagement, the teachers assimilate and take on the existing norms within the school culture. However, policy and research evidence (NCTM, 2014) have laid out a vision for effective teaching of mathematics that can be seen as another community of practice. Therefore, as novice teachers enter their school community they may be enculturated with norms that either align with or diverge from the mathematics education community’s established vision of effective teaching. As teachers navigate all of these messages or “norms”, each teacher experiences a unique journey from a more peripheral member to a more central level of engagement in his or her role. When analyzing the

discourse within a classroom, if we consider that each teacher is on a journey to become a more effective facilitator of mathematical discourse, we can attempt to understand the factors that afford and hinder teachers' progress by characterizing high-quality discourse practices.

By approaching the study of mathematical discourse from a situative perspective, the view of teachers' practice shifts from an individual succession of behaviors to a form of social interaction with learners. Skott described this shift in his statement,

“Practice is a social phenomenon and not somebody's practice. It includes the joint constitution of norms for participation and consists of the joint, but still distinct, ways of being and of being together developed by people who establish partially overlapping contexts in a certain arena” (2009, p. 29).

Skott pointed to three central aspects of practice that are illustrated in Figure 2.0 and are the foci of this study. First, the *joint* nature of practice is represented through the interactions between students and teachers. These interactions, however they exist, inform and build the classroom norms that continually direct the nature of instruction. This study seeks to examine the specific interactions when teachers and students construct discourse within mathematics lessons, as shown by the arrows from teacher to student and vice versa. Secondly, the individual contexts (e.g. knowledge, epistemological beliefs, efficacy beliefs) of all members impact the teaching and learning within a classroom, which is represented by the dotted lines encapsulating the students and teacher. These signify their *distinct ways of being* that overlap and impact one another within the classroom arena. Although important to acknowledge and understand, I do not address the individual contexts the students bring to the classroom. Instead, I focus on teachers' *distinct ways of being*, denoted by the highlighted teacher

portion. Third and finally, the highlighted outer box represents the classroom and school contextual factors. This study investigates the impact of these contextual factors that compose the *arena* of learning.

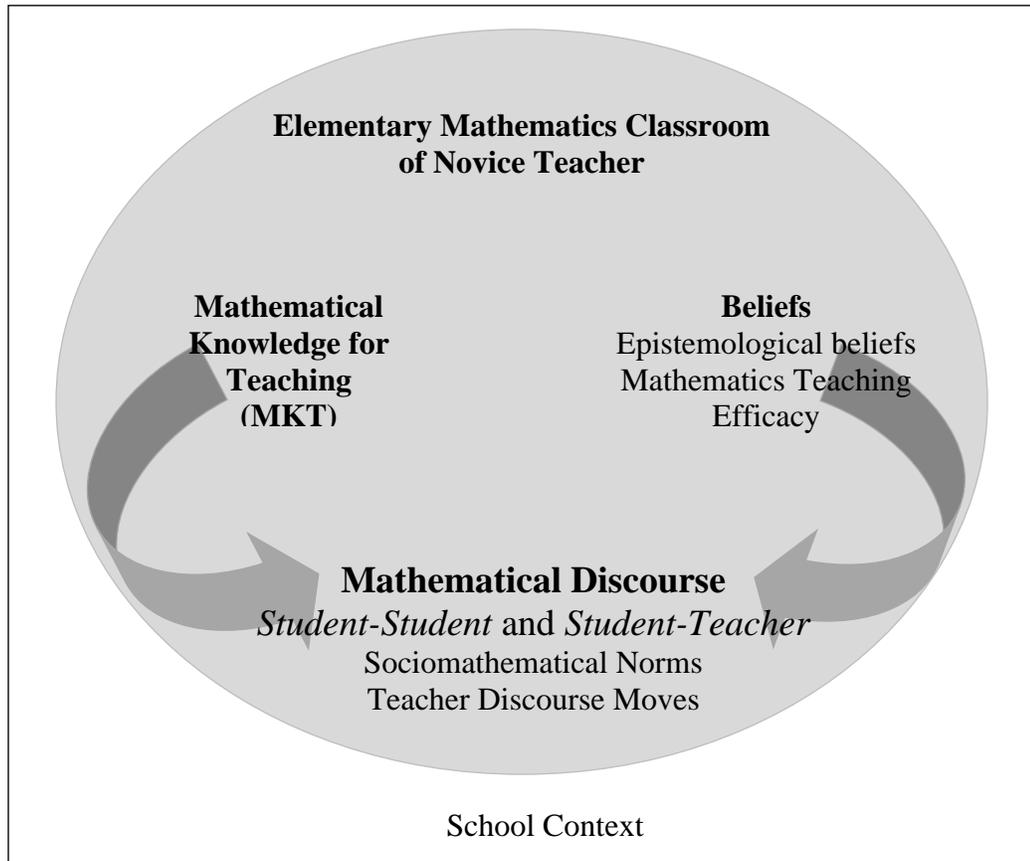


Figure 2.1: Conceptual model of the study

The subsequent review of the literature is organized using the conceptual map presented in Figure 2.1. First, mathematical discourse is the target outcome in this study and therefore an examination of research and literature on mathematical discourse will initiate the review. Next, the individual context of the teacher, and in particular the novice teacher, will be considered by synthesizing how the field has analyzed three key attributes of a teacher of mathematics: mathematical knowledge for teaching, mathematical epistemological beliefs,

and mathematics teaching efficacy. Last, the scope will expand from the teacher to examine current research on the impact of the *arena* of school context on student learning, as shown in the encapsulating box in Figure 2.1

Discourse in the Mathematics Classroom

If students are to engage in authentic practices of mathematicians, then they need opportunities and explicit guidance for how to effectively discuss solutions and methods with their fellow classmates. Construction of knowledge relies on interactions and the exchanging of ideas, and it is through the interactions with the teacher and peers that students build an understanding of the mathematics content and how to reason as a mathematician (Sfard, 2000). The mathematics education field has defined “mathematical discourse” as the communication of mathematical ideas, including the explanation, clarification, and justification of those ideas (NCTM, 2000; 2007). The following review of literature on mathematical discourse will first look at research on sociomathematical norms (Yackel & Cobb, 1996) and then branch into research on specific discourse practices or moves. Lastly, specific frameworks that have been created to study and/or improve discourse practices will be reviewed.

Sociomathematical Norms

As students enter a classroom they quickly begin to notice how their actions and words are accepted or reprimanded; they develop a sense of what is expected from the teacher or the social norms of the classroom. In their seminal work, Yackel and Cobb (1996) concluded that there are specific processes during mathematics instruction, such as how solutions are presented or how a disagreement with a concept is handled, that are specific to

the discipline of mathematics. They termed this set of norms as sociomathematical norms. Yackel and Cobb (1996) analyzed how specific sociomathematical norms (i.e., “mathematical sophistication” and “acceptable mathematical explanation and justification”) are established and how they play a key role in the formation of students’ mathematical beliefs and values. One key finding from this work is that sociomathematical norms are not preset and then imposed on the classroom, but instead they are developed and refined through the interactions between the teacher and students. In Figure 1.0 that was introduced in the discussion of the theoretical framework, the integrated nature of sociomathematical norms and classroom interactions are represented by the strategic placement of sociomathematical norms within the mathematical discourse component of the diagram. The sociomathematical norms are the foundation to acceptable involvement in the classroom mathematics community.

The work of Michaels, O’Connor, & Resnick (2008) speaks to years of research within classrooms that describes the sociomathematical norms or “norms of deliberative discourse” within the mathematics community (pg. 285). Michaels and colleagues term the discourse practices that comprise the sociomathematical norms of a classroom as “Accountable Talk” and delineate three facets including *accountability to the learning community*, *accountability to standards of reasoning*, and *accountability to knowledge*. This delineation of accountability emphasizes the role discourse plays establishing the sociomathematical norms.

Initially within a classroom, students need to be *accountable to the learning community* by being respectful of each other and perceiving each other as valuable,

contributing members. The teacher is not the sole bearer of knowledge, but instead classmates question one another and look to each other for help in building ideas. Accountability to one another is developed by implementing conversational prompts that have students restate one another's ideas or respectfully agree or disagree with methods or ideas (Chapin & O'Connor, 2001). Progressively more difficult, *accountability to reason* and *accountability to knowledge* are more complex. As students explain their ideas and negate one another's conclusions, the premise of the idea (*reason*) has to be taken into consideration and made an active part of the conversation. This uncovers the logic behind students' methods. *Accountability to knowledge* is the most difficult of the three facets because the question arises of what constitutes "authoritative knowledge" (Michaels et al., p. 289) and how are students guided to this knowledge. How the teacher creates this accountability and how the students support or challenge this accountability shapes the sociomathematical norms.

In order for students to hold each other accountable, Walshaw and Anthony (2008) highlight that "social and academic outcomes are occasioned by a complex web of relationships around which knowledge production and exchange revolve" (p. 521). Within this model, how the teacher clarifies obligations to students and how he/she provides opportunities for all students to engage in dialogue impacts how students interpret their rights in the classroom. In the case of the classroom, the opportunities teachers provide for students to share their ideas and how they manage these opportunities for all students influences the ways students are positioned. It seems that in some classrooms there might be disconnects between the "rule" to participate and actual level of dialogue that occurs due to how the

teacher calls upon students. For example, work by Ball (1993), found that certain students tended to dominate the conversation and sometimes without knowing, a teacher's overtly positive response to these students can create a norm that those students' ideas are more valuable. This creates dissonance between the expectations of equitable participation because there is this inconsistency in the type of participation that is valued.

Specific Discourse Moves

The way a teacher facilitates classroom discourse has been termed "teacher moves" within field (Chapin, O'Connor, & Anderson, 2013) in that the questions and comments said by the teacher "move" the discussion in different ways. These teacher moves reinforce the sociomathematical norms of a classroom. A teacher cannot claim that his/her students hold each other accountable (Michael, et al., 2008) if the only person that comments on students' responses is the teacher. While the teacher moves within the classroom define the sociomathematical norms, at the same time specific types of teacher moves, such as pressing for explanation, will not be effectively reciprocated within the classroom if not supported by the norms. Furthermore, while increasing student explanation is often related to increased student learning outcomes (Hiebert & Wearne, 1993), simply talking is not the basis of effective learning. The link between student discourse and learning is complex. Over the past decade, researchers have taken a promising interest into the specific nature of teacher and student interactions within the mathematics classroom that result in effective discourse practices (e.g. Truxaw & DeFranco, 2008; Kazemi & Stipek, 2001; Nathan & Knuth, 2003; Van Zoest & Enyart, 1998; Hufferd-Ackles, Fuson, & Sherin, 2004). This area of research has acknowledged that the traditional pattern of classroom communication characterized by

teacher initiation, student response, and teacher evaluation of response (IRE; Mehan, 1979; Turner, Midgley, Meyer, & Cheen, 2002) are not effective models for classroom discourse that supports learning (Franke, Kazemi, & Battey, 2007). In efforts to understand effective means of classroom discourse, researchers have investigated different aspects of specific teacher moves. In the following subsections, the specific teacher moves of probing for further explanation, connecting students' ideas, and promoting student-to-student discourse are detailed and exemplified by research.

Teacher probes for further explanation. Within situative theory, the learning process relies on explanation and justification of ideas because it is through these exchanges that students develop understanding and refine their thinking (Forman & McCormick, 1995). The teacher directly influences learning through the ways he/she probes students to elaborate on their ideas and justify their reasoning. This type of probing has been shown to increase the quality of explanations from students, impact student-to-student interactions, and is linked to higher student achievement (Kazemi & Stipek, 2001; Yackel & Cobb, 1996; Webb, Nemer, & Ing, 2006; Schleppenbach & Perry, 2007).

In a study of four upper elementary mathematics classrooms, Kazemi & Stipek (2001) documented differences in how teachers pressed students or asked for further explanations or clarification. In lessons characterized as “high press,” teacher-student interactions involved students providing an argument for their idea, making connections between multiple ways to solve problems, using errors and learning opportunities, and collaborating with one another. For example, in certain lessons, students were not allowed to explain their solution by regurgitating the steps they undertook, but instead the teachers

pressed the students to justify their strategies. Students were required to articulate “why” their strategy worked, which the researchers noted deepened the students’ conceptual understanding. Although this work did not provide explicit detail of how teachers created the learning environments, Kazemi and Stipek (2001) did provide examples of teacher and student interactions that were considered “high press,” shedding light on how the teachers’ probing influenced students’ discourse.

Not only does probing from the teacher influence the types of student-teacher interactions, findings from Webb, Nemer, and Ing (2006) also show that the type of teachers’ probing affects student-to-student interactions. In their analysis of whole-group and small-group discussions in three elementary classrooms, Webb and colleagues found the degree to which students’ explained their thinking to one another when in small group was significantly different based on the types of explanations that were solicited by the teacher in whole-group instruction. In the classrooms where students were less likely to be probed for further explanation, pair discussions were characterized by ambiguous explanations or just presentations of the perceived answer. It seems that students modeled the discourse structure that was imposed by the teacher. Furthermore, Webb and colleagues found that student achievement was significantly higher for students in the classroom where the teacher probed for further explanation (2006). This link to student achievement further supports the relationship between student explanation of their answers and student understanding (Kazemi & Stipek, 2001).

Although Webb’s work used a small sample and prior achievement was not accounted for, other work by Schleppenbach and colleagues (2007) further supports the idea

that extended explanation is connected to student achievement. Exploring the achievement gap between Chinese and US students, Schleppenbach and colleagues found that Chinese teachers probed for extended explanations more often than US teachers and that Chinese students' responses were more likely to be centered on their method or reasoning over procedural computation. While no causal claims could be made, the differences in types of probing by teachers surfaces as a difference between the teaching styles in the two countries.

Teacher connects students' ideas. In addition to encouraging and eliciting student explanations, the teacher needs to connect students' ideas in a meaningful way in order to help students build their knowledge. Supporting early work by Doyle and Carter (1984), McClain and Cobb (2001) found in a case study of one teacher that her solicitation of students' ideas did not proceed further than simply having students share. This method of "show and tell" needs the guidance of the teacher to make explicit connections to the mathematical concepts and thinking. Kazemi and Stipek (2001) found that teachers characterized by "high press" strategies provided the opportunity for different solution methods to be shared and then explicitly addressed the relationships between strategies. This was necessary for students to develop conceptual understanding.

Similar to Kazemi and Stipek (2001), other researchers have compared teachers' facilitation of mathematical discourse and how they connect various students' ideas (e.g., Truxaw & DeFranco, 2008). For example, in a study of seven teachers, Truxaw and DeFranco (2008) characterized teachers' styles of discourse as dialogic, or more interactive, and univocal, or more directly stated. A more dialogic style was illustrated with examples from transcripts in which the teacher continually connected students' contributions back to

the original question or problem. Neither the original problem nor its answer was seen as the goal, but instead, the discussion of strategies and the connection between them was seen as most important. In contrast, teachers who used more univocal discourse tended to ask for students' responses and explanations but then moved to the next problem without revisiting the problem or connecting students' ideas. The explicit connection of students' ideas was a defining feature of the classroom discourse within this study, and lessons that were more dialogic in nature promoted students' conceptual understanding (Truxaw & DeFranco, 2008).

To offer teachers support, Smith, Hughes, Engle, and Stein (2009) outline five practices that teachers can use to create mathematical discussions that will “build on and honor student thinking while ensuring that mathematical ideas at the heart of the lesson remain prominent” (p. 550). The five practices are 1) anticipate student responses, 2) monitor students' work on and engagement with the tasks, 3) select particular students to present their mathematical work, 4) sequence the responses, and 5) connect different responses and tie to key mathematical ideas. The five practices provide teachers with a systematic way to build a classroom environment that will support purposeful interactions and connect ideas.

Teacher promotes student-to-student discourse. One of the goals for the mathematics classroom is that students are accountable to one another and not just the teacher (Michaels, O'Connor, & Resnick, 2008), but it is difficult to sustain effective student-to-student discourse. Webb et al., (2008) illustrated that in small groups students mirror the types of mathematical discussions they are accustomed to in whole group, supporting Sfard and Kieran (2001) in their statement that “the art of communicating has to be taught,” (p. 70).

Even when giving explicit attention to student-to-student discourse in instruction, facilitating and sustaining it is a challenge. Nathan and Knuth (2003) provide interesting insights into the efforts of one teacher as she consciously attempts to shift the mathematical authority of the classroom to place more autonomy in the students' hands and increase their communication with each other. The teacher purposefully decreased her analytical scaffolding when presenting mathematics content and decreased her responses to students' questions and/or ideas in order to increase students' contributions to one another. They also reported that the transcript analyses exposed misconceptions that students struggled with as they tried to resolve disagreements concerning mathematical content. Even though the teacher received professional development, the difficulties of promoting student-to-student discourse were made clear. Michaels and colleagues caution about the difficulties of building accountability to knowledge (2008), which is exemplified by the students in this class.

One practice that has been found to foster student-to-student discourse is the practice of revoicing, which is when the teacher restates a student's idea. Philipp (2006) stated

Revoicing serves to clarify or amplify an idea and allows the teacher to substitute mathematical vocabulary for everyday words or redirect the conversation. Beyond these goals revoicing can communicate a way of thinking about doing mathematics, a respect for student ideas, and an encouragement of students' developing mathematical voice (p. 223).

When a student engages in revoicing, researchers have coined it "restating" (Chapin et al., 2009). In order to restate another classmate's idea, students must listen to one another and then help one another clarify if ideas are not communicated as intended. The action of

restating allows students to legitimize one another's claims and also opens the door for them to add their own reasoning to support or argue against the claim (Forman & Ansell, 2002). Work by Forman & Ansell (2002) analyzed mathematical discourse in two classrooms and found that students restated one another's ideas as an initiator of classroom discussions. Within these discussions, students drove the discourse through effective argumentation and explanation. The discourse practice of restating promoted the transfer of authority from teacher to student and seemed to contribute to the sociomathematical norms of these classrooms.

In addition to the work of Forman and Ansell (2002), Hufferd-Ackles, Fuson, and Sherin (2004) illustrated how student authority can be cultivated in a classroom. In a case study of one third-grade teacher, when the teacher left on maternity leave, the students continued to initiate further explanation of problems (Hufferd-Ackles, Fuson, & Sherin, 2004). The substitute teacher had to become accustomed to the classroom community that was in place. Students restated one another and added to their own ideas. This level of discourse did not happen immediately, but through a year of co-construction by the teacher and students, the authority seemed to shift towards more student-centered discourse practices.

These examples from research provide evidence that the sociomathematical norms were cultivated to allow for effective student interactions. However, revoicing or restating is not productive if the sociomathematical norms of the classroom do not reinforce respect of students as mathematicians and uphold that the substance of the revoicing/restating must be mathematically focused (Michaels et al., 2008; Yackel & Cobb, 1996). For example, if a

student restates a classmate's idea and adds criticism that is not mathematically valid, but instead is focused on other contextual factors (i.e., neatness), the mathematical discussion may suffer. Teacher support of revoicing/restating strategies is crucial to ensure that sociomathematical norms support learning.

Summary. The nature of classroom discourse has been explored in recent research to better understand how different teacher moves establish certain norms and attend to the mathematics (i.e., probing for explanation, connecting students' ideas, and promoting student-to-student discourse). This research on classroom discourse has commonly used in-depth qualitative analysis of a small sample of teachers (1-4 teachers) (e.g., Hufferd-Ackles, Fuson, & Sherin, 2004; Kazemi & Stipek, 2001; McClain and Cobb, 2001). Through this comprehensive study of classroom discourse, researchers have been able to categorize and describe mathematical discourse practices. The next section provides a review of specific frameworks that have emerged from this work, along with others, that have been used to categorize types of discourse and to make meaning of their influence to instruction.

Frameworks for studying classroom discourse

The previous sections provided a synthesis of the research findings about sociomathematical norms and teacher moves in elementary mathematics classrooms. The following section reviews the frameworks used for studying classroom discourse. As researchers have stepped into classrooms to examine discourse practices, they have created frameworks to organize their processes and findings, some taking a finer grain size than others.

First, several researchers have broadly documented discourse practices through a holistic view of teachers' instructional practices. For example, work surrounding the implementation of Cognitively Guided Instruction (CGI) (Carpenter & Fennema, 1992; Carpenter, Fennema, Franke, Levi & Empson, 1999; Carpenter, Fennema, Franke, Levi, & Empson, 2002) has utilized the "Levels of Engagement with Children's Mathematical Thinking" framework to systematically assess how teachers change during and after participating in the CGI professional development program; the framework includes attention to how teachers utilize discussion to elicit student ideas. Steinberg, Empson, & Carpenter (2004) used the levels of engagement to describe how one teacher transformed over the course of one school year, incorporating more opportunities for student explanation and explicitly teaching expectations for class discussions.

Other standards-based observational protocols incorporate aspects of classroom discourse in their frameworks for analyzing teaching practices. The Mathematical Quality of Instructional (MQI) observational protocol (Hill, Blunk, Charalambous, Lewis, Phelps, Sleep, & Ball, 2008; Hill, Kapitula, & Umland, 2011) attends to student discourse within the element of "richness of the mathematics." Within this dimension, MQI users are able to describe lessons in terms of the teacher's and students' use of mathematical explanation and explicitness in reasoning. Researchers have used the MQI to examine mathematical practice and analyze relationships between practice and teacher knowledge (Hill, et al., 2008) and student achievement (Hill, Kapitula, & Umland, 2011). Another standards-based framework, The Mathematics Scan (M-Scan) provides an efficient, holistic perspective of a lesson and is used to examine implementation of mathematics lessons by focusing on tasks, discourse,

representations, and lesson coherence (Berry, et al., 2013). For the discourse construct of the framework, lessons are scored based on the type of discourse community that is created in the classroom and the level of explanation and justification that students communicate within the lesson. By describing mathematics lessons in terms of multiple constructs, both the MQI and M-Scan provide a more holistic look into the mathematics instructional practices of teachers. However, these frameworks do not offer a fine-grained picture of the type of interactions that create the discourse community within the classroom.

To better understand how rich discourse is created within the classroom, Hufferd-Ackles, Fuson, and Sherin (2004) conducted in-depth case study research with four novice teachers to detail the “math talk” within the classrooms. Lesson transcripts, along with other triangulating evidence, were analyzed to create a framework, *Levels of the Math-Talk Learning Community*, that characterized the progression from a more traditional, teacher-directed classroom setting, to a more standards-based, talk-focused classroom setting. The framework documents teacher actions and student actions along trajectories in the areas of (a) Questioning, (b) Explaining math thinking, (c) Sources of mathematical idea, and (d) Responsibility for learning. The trajectories progress through four levels (Level 0-3). For example, in the area of questioning, a teacher could be at a level 0, described as the “teacher is the only questioner’...where short frequent questions function to keep students listening and paying attention to the teacher” (p. 88). The lesson transcripts were used as evidence of each level. This intensive documentation in terms of specific components and levels of math talk provide a guide for practitioners and an analysis tool for researchers. This work echoes the research on sociomathematical norms, but provides operationalized examples of how

these norms are created and sustained in the classroom. The Levels of the Math-Talk Learning Community Framework has been used with pre-service and in-service teachers to scaffold teacher change (e.g., Hufferd-Ackles, Fuson, Sherin, 2004, Drake, 2000; insert a couple more?), but the authors call for future research to better understand how teachers change their discourse practices and alternative ways to support this change.

In the past few years, researchers have begun to more precisely examine the type of interactions that make up classroom discussions with attention to the moves the teacher uses to create those interactions. In their proposed framework of teacher moves, which they categorize as “the deliberate actions taken by a teacher to mediate, participate in, or influence the discourse in mathematics classrooms,” (p. 307), Krussel, Edwards, and Springer (2004) identify key elements of teachers’ actions within discussions that should be examined to understand their impact on students learning. These elements include the purpose of the move (i.e., give directions, create disequilibrium) the setting of the move (i.e., sociomathematical norms), the form of the move (i.e., probe, request for elaboration), and the consequence of the move (i.e., shift in cognitive level, structure of discourse). Krussel, Edwards, and Springer (2004) propose this framework as a professional development tool, and the idea of having teacher reflect on their purpose for certain moves within a discussion and then connecting that with the consequence is a powerful idea. However, while the authors list the different forms a move can take (i.e., challenge, request), they do not operationalize how the purpose, setting, or consequence of the move are measured or observed. Future work may provide more information as how these elements can be observed and measured to serve the growth of teachers.

Another framework by Truxaw and DeFranco (2008) provides a highly structured procedure that maps teacher and student moves in an effort to model how teacher and student interactions create opportunities for more univocal or more dialogic discourse, with dialogic discourse more aligned with building students' conceptual understanding. Truxaw and DeFranco encompass elements of the setting, form, and consequence of moves (Krussel et al., 2004) by applying line-by-line coding of lesson transcriptions and organizing the lessons into sequences that account for the succession of moves and their relationship to one another. For example, a teacher and/or student move (a single question or answer) is grouped with another move to form an exchange. Exchanges are then grouped into sequences, and then lastly all the sequences needed to accomplish a task are titled an episode. The researchers documented the overall purpose of a sequence as more univocal if the purpose is to convey information and as more dialogic if there are elements of what they term exploratory talk (allowing students to work through an uncertain idea), accountable talk (Michaels, O'Connor, Resnick, 2007), or generative assessment (mediating to promote students' monitoring of thinking). Sequence maps were created to visualize the flow of the discourse in the classroom.

This extensive framework has over 50 categorizations of discourse moves that the researchers collapsed into five types of talk or assessment. The amount of detail is impressive, but the resulting visuals make it difficult to look at patterns across sequences and lessons. Correnti et al. (2015) have advanced the work of Truxaw and DeFranco (2008) by creating the Analyzing Teaching Moves Guide (ATM) to capture the patterns of discourse moves with explicit attention to how the moves are sequenced to position students to think

and participate. The framework is used to code whole-group classroom discussions (in mathematics and language arts lessons), and involves several codes for teacher moves that are categorized as initiating moves, which elicit student contributions, and rejoinder moves, which describe the teacher's response to student contributions. The list of moves attends specifically to how sequences of moves put the students at the center, or sidelines, of the thinking and communication.

When coding a teacher move, the coder must consider the previous and sequential student moves to construct the meaning of the move (Scherrer & Stein, 2013). This process highlights the importance of considering the context surrounding teachers' moves and not just looking at them in isolation. Through coding in context and considering the position of moves, the ATM provides an opportunity for more patterns to emerge than just the general trend of dialogic or univocal that was captured with Truxaw and DeFranco's framework. Furthermore, perhaps the most powerful component of the framework is the visualizations that are created from the coding that show concretely, in time, when each move is used throughout the classroom discussion. This visual representation, called an infographic, includes color-coded moves positioned on a horizontal timeline to show the sequential progression. This allows for an analysis of the progression of moves within a lesson as well as an analysis of the moves produced across lessons.

Using the ATM, Scherrer & Stein (2013) analyzed the impact of an 8-hour professional development program that taught teachers the moves and how to code transcripts. They found that teachers increased their ability to notice interactions between teacher and students and shared ways that their understanding of the moves impacted

discourse practices in their classrooms. Although the teachers were not able to explicitly reason about how the moves afforded learning opportunities to students, they did reflect on how they used the moves to analyze and increase student responses. Teachers shared a common feeling that “there are so many uncontrollable variables in the classroom that it was nice to feel empowered at least in regard to how a discussion might be shaped” (p. 120).

Summary

The types of discourse practices within mathematics classrooms either support or hinder students’ understanding and ability to actively engage with their peers. The mathematics education community emphasizes the necessity of effective discourse through their explicit attention to communication (NCTM, 2000, 2014; CCSSM, 2010). Research has attended to different aspects of the discourse within elementary mathematics classrooms, and in my review I concentrated on how researchers have studied specific discourse interactions within the classroom and how these interactions embody the overall sociomathematical norms of the classroom. Also, I detailed several frameworks that have been used to characterize and study discourse.

Within the synthesis of the discourse frameworks, the ATM guide (Stein, et. al, 2015) diverges from the other frameworks in the unique opportunity it provides researchers to describe classroom discourse at the interaction level while also painting a picture of how the classroom members are positioned within the overall classroom community. That is, thorough analysis of the sequence of teacher moves, discourse patterns are discovered; these discourse patterns are evidence of the expectations teachers have for students and the norms of the classroom. Future research using the ATM guide can provide valuable insight into how

direct moves of the teacher over time establish certain sociomathematical norms, and moreover how certain patterns of teacher moves can begin to change these norms if they are not aligned with effective practices.

However, when considering the line-by-line coding of lesson transcripts that is necessary for analytical methods using the ATM guide (Stein, et al., 2015), the benefits of observational protocols are illuminated. Perhaps the limitations and advantages of different measures can be reconciled by adopting multiple perspectives within a single study. By analyzing classroom discourse from a more holistic perspective with an observational measure and then narrowed the focus by analyzing specific teacher moves (i.e., coding with ATM) a more complete picture of student and teacher discourse can be captured.

Furthermore, research on discourse has often involved case study work used to document detailed accounts of a select teacher's use of discourse (i.e., Hufferd-Ackles, Fuson, and Sherin, 2004; Steinberg, Empson, & Carpenter, 2004). These studies provide rich information about the nature of the teacher's interactions within his/her classroom; however, little information is presented about the teacher that would provide a context for these interactions. For example, in Truxaw and DeFranco's work (2008), three teachers' classroom discourse practices were analyzed to describe models of teaching; however, the only information provided about the teachers was his/her years of experience, class composition, and classroom layout. Teachers' discourse practices do not occur in a vacuum, and it is important to understand how teacher attributes (e.g., knowledge, efficacy) as well as school context (e.g., administrative support) afford teachers with different discourse practices. From a situative perspective it is important to understand individual characteristics when trying to

understand how a person is engaging in their community of practice. Several key individual contexts are identified in the next section and explored within the current literature.

Situated Nature of Practice: Teacher Attributes

In light of the research on discourse practices in elementary classrooms, the effective use of discourse within classroom is situated within the sociomathematical norms imposed by the classroom, and the teacher is a critical player in the creation of this community. Just as students engage in differing levels of participation as a result of a number of contextual factors, teachers differ in their proficiency in creating effective mathematical discourse. Teachers' proficiency in orchestrating discourse in their classrooms, which Lave and Wenger (1991) would identify as their level of authentic participation in their community of practice, is influenced by numerous factors. Some influential factors include their mathematical knowledge, their epistemological beliefs (beliefs about the nature of learning and teaching), and their efficacy beliefs. Referring back to Figure 2 teachers' mathematical knowledge for teaching, epistemological beliefs, and efficacy beliefs are represented within the teacher box, and these are the teachers' "distinct ways of being" (Skott, 2009, p. 29). Furthermore, level of experience bears influence on a teachers' practice (Darling-Hammond, 2000; Rivkin, Hanushek, Kain, 2005). This study aims to characterize the discourse practices of novice teachers and therefore research on novice experiences will initiate the review of individual context.

Novice Teachers

One defining characteristic of a teacher's journey is his/her level of experience. This study examines a unique teacher population that has limited experience in their own

classrooms (novice teachers). As pre-service teachers graduate from their preparation programs and enter their first classroom, they undergo a transition to the teacher of record for a group of students. Many of these teachers were students during the movement towards standards-based mathematics; however, reform initiatives of the past decades have had a less-than-intended impact on how mathematics is taught across the United States (Hardy, 2004). If novice teachers did not experience standards-based mathematics in their formal learning, then they are being asked to teach in a way that is different from how they learned. Teacher preparation programs attempt to transform pre-service teachers' model of teaching from an authoritarian acquisition of knowledge to a more cultural participatory model (Cobb, Stephan, McClain, & Gravemeijer, 2011; Yackel & Cobb, 1996; Cobb, 1994). Unfortunately, as novice teachers enter the field, teachers that still hold tightly to the authoritarian role of the teacher to transmit knowledge often influence them. In addition to navigating mixed messages about quality teaching practices, novice teachers also face, for the first time, the pressure to produce high scores on standardized assessments that are not necessarily a direct measure of standards-based practices (CITE). As a result, it is not surprising that many novice teachers revert back to more authoritarian teaching methodologies for which they are more comfortable.

Current research on novice teachers is slim in terms of understanding how they implement standards-based practices. On the other hand, research is more abundant that compares novice teachers to more experienced teachers in terms of student achievement (e.g., Darling-Hammond, 2000; Rivkin, Hanushek, Kain, 2005) This body of research presents conclusions that first-year teachers tend to perform significantly worse compared to

more experienced teachers (Rivkin, Hanushek, Kain, 2005); however, the measures of performance are student standardized test scores. Furthermore, when using standardized test scores, studies show that there is a plateau effect in the second year (Hill, Kapitula, & Umland, 2011); that is, differences found between first-year teachers and more experienced teachers are no longer statistically significant for teachers in their second year compared to more experienced teachers. So while research supports that experienced teachers are “better” than novice teachers if the measure of quality is in standardized tests, a different measure is needed. To understand the content-specific quality of instruction, teaching practices of novice teachers need to be examined using a measure that is aligned with the standard for instruction. In mathematics education that standard is standards-based mathematics teaching (NCTM, 2000, 2014; CCSSM, 2010).

In broader research differentiating between novice and experienced teachers, studies of stressors have shown that planning and instruction (Forgasz & Leder 2006) and work load (Kyriacou & Kunc, 2007) are top stressors for novice teachers while the general teacher population have shown that student behaviors, lack of student engagement, and lack of support to be stressors as well (Chaplain 2008; Geving 2007; Davidson 2009). One study of secondary, novice teachers found that novice teachers with unified departments and strong support systems managed their stressors related to standards-based mathematics better than those without supportive teams (Lewis, 2007). More attention is needed specifically on the instructional practices of novice teachers due to the stressors they face in this particular area. If novice teachers are experiencing stressors with their planning and implementation of standards-based instruction, more information is needed regarding how their personal

teaching beliefs, knowledge, and support systems are aligning with the use of standards-based instruction.

While not common in the field, one study of teacher quality in Ohio, the Teacher Quality Partnership (Kinnucan-Wesch, Franco, & Hendricks, 2010) did attend to novice teachers' knowledge and practice. This study found that novice teachers' emotional support of students was predictive of instructional support, but that these dimensions of teaching practice were not related to the teachers' mathematical knowledge for teaching. This study provided a peek into novice teachers' classrooms, but it did not utilize a measure of standards-based mathematics instruction. The study did not examine the use of standards-based practices but instead utilized the Classroom Assessment Scoring System (CLASS; Pianta, La Paro & Hamre, 2008) to comment on teaching practices. While informative into the culture novice teachers are creating in their classrooms, without particular measures of standards-based practices, it is difficult to understand how novice teachers are implementing these practices.

More research is needed to allow the mathematics education field to understand how novice teachers, and experienced teachers for that matter, are implementing standards-based practices. This line of research will add to research utilizing student achievement data as a measure of teaching quality by providing insight into the internal work of the mathematics classroom.

Mathematical Knowledge for Teaching

What teachers know impacts what they teach and how they teach. In mathematics education, there has been a concerted effort to define and study the different aspects of

knowledge and how they influence teaching practices and student learning. In their initial efforts, researchers accounted for knowledge of mathematics by using number of content courses in preparation work, experience, and tests of mathematics (Greenwald, et al., 1996). However, these measures of teacher knowledge do not attend to identifiable elements of what exactly teachers know. Other efforts to measure teachers' mathematical knowledge were also employed using items that were similar to items that students would be given (e.g., Harbison & Hanushek, 1992), measuring knowledge of mathematical subject matter. However, Shulman (1986, 1987) in his seminal work advanced the notion of teacher knowledge to include aspects beyond subject matter knowledge, including student misconceptions and useful representations, which he terms pedagogical content knowledge. This work has been central to our understanding that teaching is not merely being able to do the math, but involves a more complex sense of knowing.

Ball and colleagues (Ball & Bass, 2003; Ball, Thames, & Phelps, 2005; Hill, Shilling, & Ball, 2004) further delineated Shulman's constructs of subject matter knowledge and pedagogical knowledge as shown in Figure 2. They conceptualized subject matter knowledge to include common content knowledge, which is the knowledge that students should develop, and specialized content knowledge, that is knowledge that is not expressed to students but necessary to facilitate learning. Specialized content knowledge is characterized as mathematical work not done by non-teachers, such as understanding processes for proving the generalizability of strategies used by students. Ball and colleagues also went on to distinguish Shulman's pedagogical knowledge, as shown by the right side of Figure 2.2, into knowledge of content and students and knowledge of content and teaching. Knowledge of

content and students refers to a teacher’s understanding of how students learn best and where the challenges may lie for them to grasp a mathematical concept. Knowledge of content and teaching refers to the knowing how to structure tasks and which tools or representations to select for a mathematical concept. All of these components of knowledge, which the field has termed mathematical knowledge for teaching (MKT), are interrelated and at times difficult to isolate.

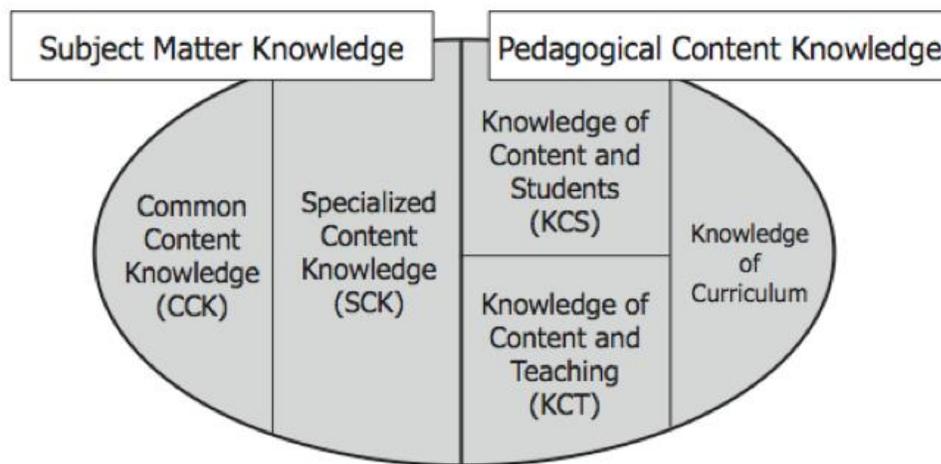


Figure 2.2 Categorization of Mathematical Knowledge for Teaching as presented in Ball, Thames, & Phelps (2005)

Researchers have worked extensively on how to measure this specialized knowledge (Saderholm, Ronau, Brown, & Collins, 2010; Fennema & Franke, 1992). Several researchers have developed surveys, more like assessments, involving multiple-choice items and short responses that measure components of teachers’ common content knowledge, specialized content knowledge, and pedagogical content knowledge (knowledge of content and students and knowledge of content and teaching). The variety of items capture whether teachers can

solve mathematics problems like they assign students and also how teachers solve “the special mathematical tasks that arise in teaching, including evaluating unusual solution methods, using mathematical definitions, representing mathematical content to students, and identifying adequate mathematical explanations” (LMT, n.d, p. 1).

The multifaceted nature of teacher knowledge is evident when considering the challenges of orchestrating classroom discourse. As teachers attempt to solicit student thinking, push for mathematically rich explanations, and position students to have authority in the discussion, they must not only know the mathematics, but also predict how students will respond and plan how to structure the tasks. It seems that a teacher’s level of MKT would afford or limit their ability to co-construct high-quality discourse, and this relationship has been alluded to in studies of teachers’ MKT and instructional practices (Hill et. al., 2008). In their analysis of classroom instruction in relation to teachers’ MKT, Hill and colleagues coded lessons using a holistic framework that included discourse as one small piece, and they found a strong relationship between teachers’ MKT and instructional practices.

Researchers have also used the LMT survey as a measure of teachers’ MKT and found teachers’ content knowledge to be a significant predictor of student achievement gains (Hill, Ball, Blunk, Goffney, & Rowan, 2007; Hill, Rowan, & Ball, 2005). While student learning is the most important part, understanding how teachers’ knowledge is translated into practice is valuable and necessary to further promote positive student outcomes. Further study of teachers’ instructional practices, especially in terms of the discourse promoted within instruction, and connections to student achievement are necessary to better understand

how teacher knowledge impacts practice.

Beliefs about teaching and learning

Muis (2004) and Philipp (2007) point out that the mathematics education field uses the term “beliefs” to encompass many things. This study specifically studies teachers’ epistemological beliefs and efficacy beliefs. Both of these constructs will be reviewed in the following sections.

Epistemological Beliefs

Although differences of opinion still exist within the educational psychology community, there appears to be some agreement that epistemology refers to considerations of what knowledge is, how knowledge is constructed, and how knowledge is justified (Hofer & Pintrich, 1997; Muis, 2004; Schommer, 1990;). These three tenants of epistemology are agreed upon, however several researchers have extended the definition to include a developmental element of knowledge acquisition (Baxter Magolda, 2004; Moore, 2002; Muis, 2004). This developmental element of epistemology includes beliefs about how people learn in the definition. The distinctions between beliefs about knowledge and learning are continually negotiated (Schommer-Aikins, 2004), and become even more difficult when analyzing teachers’ views of knowledge and instruction. That is, beliefs about knowledge and learning seem indistinguishable when considering that teachers’ instructional practices can be seen as the operationalization of their epistemological beliefs and that student learning is the outcome of that practice. This grey area surrounding the definition of epistemic beliefs is probably the reason why the mathematics education field has continued to use “beliefs” as an

all-encompassing term for beliefs pertaining to knowledge, teaching, and learning (Phillip, 2007). While a variety of definitions have been suggested across fields, this dissertation will use the terms epistemological and epistemic beliefs interchangeably to mean beliefs about the nature of knowledge (what knowledge is), sources of knowledge (how knowledge is constructed), justification of knowledge, and acquisition of knowledge (learning).

Categorization of epistemological beliefs. In addition to disagreements with how epistemological beliefs should be defined there are also challenges when attempting to categorize these beliefs. From her seminal work, Schommer (1990) categorized student's epistemic beliefs about mathematics and social studies as "naïve" and "sophisticated." Other work by Hofer & Pintrich (1997) and Schonfeld (1989) used the language "appropriate" and "inappropriate." However, Muis (2004) points out that this language communicates negative connotations and advocates for terminology with less value judgment. Muis (2004) proposes using "availing" to describes beliefs that are linked to student learning and achievement, and "nonavailing" for those beliefs that do not affect or support learning. Table 2.1 displays different beliefs about mathematics knowledge and learning that have been classified on the availing/non-availing continuum.

Table 2.1
Epistemic Belief Continuum

Availing	Non-Availing		
Mathematics as process orientated	Mathematics as rule-oriented	Brown et al. (1988)	7 th and 11 th graders
Mathematics is a complex, highly interrelated conceptual discipline	Mathematics is a fragmented set of rules and procedures	Garofalo (1989)	secondary students
Mathematics is driven by concepts	Mathematics is driven by rules and memorization of procedures	Diaz-Obando, Plasencia-Cruz, & Solano-Alvarado (2003)	secondary students
Solving mathematics problems might take time	Mathematics problems should be solved quickly	Frank (1988)	middle school students
Goal of mathematics is understand the concepts and apply them	Goal of mathematics is to obtain a correct answer	Frank (1988)	middle school students
In mathematics there may be more than one solution and a variety of methods are valued.	In mathematics there is only one solution and one method is preferred.	Spangler (1992)	elementary-graduate school
Mathematics involves performing tasks as described by the teacher	Mathematics can involve discovery or invention	Schonfeld (1988)	Secondary students

The table shows the variety of epistemic components that researchers highlighted in their studies of student beliefs. This is evidence of the lack of consistency across the mathematics field and the necessity to clearly define what aspects of epistemological beliefs are being studied. This table also shows that majority of research has centered on students' epistemological beliefs and not those of the teacher. Research has presented the development of students' epistemologies (Perry, 1968; King & Kitchener, 1994), differentiated in beliefs based on domain (e.g., mathematics, history) epistemologies (Schommer, 1995), and relationships between epistemic beliefs and student comprehension (Ryan, 1984; Schommer, 1989; Schommer, 1990), achievement (Schommer, 1993; Buehl & Alexandar, 2005), and

motivation (Pintrich, 1990, Buehl & Alexandar, 2005). Overall these studies have shown that students with more availing epistemologies have more promising outcomes in the area being measured, whether it was comprehension or achievement. Emerging from the study of student epistemologies, researchers have redirected focus to the epistemological beliefs of teachers in the past years.

Teachers' epistemological beliefs. Just as epistemological beliefs impact students' learning, teachers' personal epistemological beliefs seem to influence various elements of their instruction (Hofer, 2001; Lee, Zhang, Song, & Huang, 2013; Pajares, 1992). However, these associations between epistemological beliefs and teaching practice have been empirically studied through an examination of pre-service teachers (e.g., Brownlee, Purdie, & Boulton-Lewis, 2001; Chan, 2004; Chan & Elliot, 2002) with few studies analyzing in-service teachers (Hofer, 2001).

Majority of the studies of pre-service teachers described changes in epistemological beliefs throughout their teacher preparation program (Brownlee, Purdie, & Boulton-Lewis, 2001); interventions that impacted beliefs (Gill, Ashton, & Algina, 2004); or cultural influences on epistemological beliefs (Chan, 2004; Chan & Elliott, 2002). Other research has begun to examine the connections between pre-service teachers' epistemological beliefs about knowledge and teaching (Cheng, Chan, Tang, & Cheng, 2009). The work of Cheng and colleagues (2009) reported that most pre-service teachers in their sample from Hong-Kong believed knowledge acquisition was a process and not innate ability and that this belief was related to more constructivist views of teaching. However, in this study teaching practices were measured through surveys and interviews about their conceptions of practice

and not observations of practice. This was also common for studies on in-service teachers such as earlier work by Hasweh (1996) that measured constructivist views of teaching based on responses to surveys.

Researchers that have used classroom observations as a measure of teaching practices have reported mixed findings in regard to the relationship between teachers' epistemological beliefs and enacted practice. Early work by Ernest (1989) found inconsistencies between teachers' professed beliefs about the nature of teaching and learning and their instructional strategies they used in their classrooms. This work was limited by a small sample size (N=4), and utilized vague definitions of beliefs surrounding learning. Other work by Kang and colleagues (2008) analyzed specific instructional practices in secondary laboratory activities and their relation to teachers' epistemological beliefs about the certainty and acquisition of knowledge. This research provided rich descriptions of three teachers' beliefs and practices and showed that instructional practices of one teacher were representative of her naïve epistemological beliefs. This teacher engaged in demonstrations in the place of student interactive laboratory activities because she felt the knowledge could be transmitted by showing the students the concepts. On the other hand, for teachers with more sophisticated epistemological beliefs, their laboratory practices varied based on their goals and teaching contexts. These findings echo the inconsistencies reported in other research (Ernest, 1989; Phillip, 2002).

Summary. The study of epistemological beliefs within the teacher education field is characterized by vague definition of epistemology and a missing link to instructional practices (Hofer, 2001). This study fills this gap by narrowing its definition of

epistemological beliefs to teachers' beliefs about mathematics as a discipline and examining teaching practice. Specifically, this study analyzes the use of discourse practices and their relationship to teachers' epistemological beliefs. This precision fills a void in mathematics education literature and will provide applications for the general teacher education field as well.

Efficacy Beliefs

In addition to knowledge and epistemological beliefs, how a teacher feels about his/her ability to actually teach, known as teachers' efficacy, influences the implementation of effective instructional practices (Tschannen-Moran, et al., 1998; Beard, et al., 2010; Goddard et al., 2000). Research on teaching efficacy draws upon social cognitive theory that asserts that individuals learn from their interactions with their environment and others around them (Bandura, 1997). Bandura (1986, 1997) describes an individual's beliefs about his/her own capabilities to successfully complete a task as self-efficacy. An individual's efficacy is developed through experiences with others (social) and their interpretations of their experiences (cognitive). Bandura (1997) classifies the influences on self-efficacy as past mastery experiences, vicarious experiences, verbal persuasion by others, and physiological responses.

For teachers, beliefs about the impact of teaching on student learning (teaching outcome expectancy, TOE) and beliefs about his/her ability to effectively teach (personal teaching efficacy, PTE) comprise the construct of teaching efficacy (Tschannen-Moran, Hoy & Hoy, 1998). Research focusing on PTE has reported that teachers with high PTE are more likely to engage in effective teaching behaviors and promote higher student achievement

(Tschannen-Moran, et al., 1998, Tschannen-Moran & McMaster, 2009; Beard, et al., 2010; Goddard et al., 2000). In their research of different sources of PTE, Tschannen-Moran & McMaster (2009) found that teachers who engaged in professional development that provided mastery experiences increased their PTE and were more likely to implement the new instructional strategy in reading. It is important to note that a teacher's personal efficacy may vary based on the context and subject matter (Bandura, 1997), and therefore I direct my attention to research focused on teachers' efficacy for teaching mathematics.

Mathematics teaching efficacy can be divided into personal mathematics teaching efficacy (PMTE) and mathematics teaching outcome expectancy (MTOE) (Enochs, Smith & Huinker, 2000). How teachers feel about their individual ability to successfully teach mathematics (e.g., addressing student questioning; explaining mathematical concepts) is defined as PMTE. On the other hand, MTOE is characterized as a teacher's belief about whether effective teaching will or will not result in student learning (Huinker & Madison, 1997).

In efforts to explore the malleability of mathematics teaching efficacy for prospective teachers, researchers have found that methods courses within elementary preparation programs can have a positive impact on prospective teachers' beliefs about their efficacy for teaching mathematics (Huinker & Madison, 1997; Newton et al., 2012; Swars, et. al, 2007; Utley, Moseley, & Bryant, 2005). Utley and colleagues (2005) found that PMTE increased throughout mathematics methods courses. Further, Swars and her colleagues (2007) duplicated these findings and showed that participants increased in different dimensions during their student teaching. These findings have been attributed to numerous factors (e.g.,

mentor teacher, school factors) that impact prospective teachers' experiences during student teaching.

More current research (Newton et al., 2012) using interviews to analyze sources of efficacy has also documented an increase in prospective teachers' mathematics teaching efficacy during teacher preparation training. Using purposeful sampling based on content knowledge, Newton and colleagues (2012) found that prospective teachers with higher content knowledge referred to verbal feedback from mentors as a common influence on their feelings of efficacy while those with lower content knowledge referred to field experiences in schools as important for their efficacy beliefs. Also, prior-learning experiences in mathematics emerged as a factor that impacted efficacy for the participants in Newton's study and in other studies as well (Brown, 2012; Charalambous, Philippou, & Kyriakides, 2008; Swars, 2005).

Much of the research on mathematics teaching efficacy has sampled from prospective teachers, perhaps due to the malleability of their efficacy early in their experiences (Hoy, 2004). Other research with in-service teachers has used efficacy as an outcome to evaluate professional development programs (Lau & Yuen, 2013; Zambo & Zambo, 2008). In these studies, researchers report that teachers experience an increase in mathematics teaching efficacy through their experiences with a particular professional development, but due to a lack of resources few actually study teachers' instructional practices. While helping teachers to become more efficacious is a positive outcome, more work is needed to understand how teachers' efficacy relates to particular mathematics instructional practices and how teachers can act upon their beliefs and change their practices (Skott, 2009).

Although there is a gap in understanding efficacy and mathematics instructional practices, one study by Enon (1995) explored the relationship of efficacy and standards-based practices with a small group of teachers in Uganda. Enon utilized a measure of general teaching efficacy and an observational checklist and concluded that teachers with higher efficacy provided more opportunities for students to engage in problem solving, asked higher-level questions, and utilized more cognitive-oriented instructional strategies. Another study by Walkowiak (2010), through latent profile analysis, found that teachers with higher levels of MKT also reported higher levels of personal mathematics teaching efficacy. Also, through analysis of a subsample of lessons within the profiles, Walkowiak found that teachers reporting higher level of efficacy demonstrated instructional practices that were more aligned with standards-based practices.

It is important to note that prospective and in-service teachers experiences are situated within the ongoing reform movement within mathematics education that often contradicts the way they learned mathematics. Research by Phelps (2010) found that a “lack of fit between [prospective teachers’] expectations and beliefs about mathematics and the nature of the mathematics in their courses” (p. 303) influenced efficacy for teaching mathematics. The lack of “fit” between teachers’ experiences with mathematics (more traditional) and new standards-based methodologies may cause a decline in self-efficacy for some. As teachers transition from more traditional methods of teaching mathematics to standards-based practices, there is a level of disequilibrium that should be addressed (Smith, 1996). As with the introduction of new standards by the National Council of Teachers in Mathematics at the end of the previous millennium (2000), the same lack of fit is present in the current transition

to the CCSS-M. Many teachers experienced traditional instruction; therefore, the current standards-based focus must be taken into account when considering levels of self-efficacy and how to improve it.

Situated Nature of Practice: School Context

Beliefs are repeatedly characterized as complex and messy; however Fives and Buehl (2012) offer a redirected focus in their review of beliefs literature. Specifically, they call out the lack of attention to the “reciprocal relationship with context and experiences” and processes through which “belief enactment may be constrained by individual and contextual factors” (p. 488). This call for research is applicable, especially in the mathematics education field, to study the incongruence between teachers’ beliefs about teaching and learning and the instructional practices they enact in their classroom in light of ongoing reform. By investigating how teachers’ individual contexts, including knowledge and beliefs, relate to their instructional decisions the reciprocal relationship between these factors can be highlighted. In moving beyond using beliefs as precursor to action, the field needs to further explore the process through which belief systems function and change and their relation to practice.

In addition to individual factors such as teachers’ knowledge and beliefs, teachers are situated in school contexts that impose numerous obligations and structures upon them (Ball & Cohen, 1999). The organizational factors of school, the teaching conditions in which teacher work, and their resources bear influence on their beliefs and instructional choices, but most studies on teachers’ beliefs and instructional practices have not attended to how these contextual factors influence the relationship between them (Fives & Buehl, 2012). It seems

that studies limit their conceptualization of context to teachers' years of experience and school demographics, but these factors do not sufficiently capture the nuances of teaching. Hill and colleagues (2008) dove into the specificity of context as they explored the case of three teachers that diverged from their finding that higher MKT was associated with higher quality instruction. Through interviews and analytic coding of lessons, they aimed to determine factors that mediated the expression of MKT in instruction. Hill's team found that teachers' opinion of curriculum materials was the common factor among these three teachers who were outliers. The teachers negatively viewed the adopted curriculum and developed supplemental resources that fragmented their objectives and as a result lowered the quality of their instruction. The insight into the context of these teachers' practice in relation to knowledge provides valuable information about how interpretation of curriculum can impact the translation of teachers' knowledge. More studies are needed to delve more deeply into the unique contexts of teaching to analyze their relationships and patterns that can be useful to advance the profession.

Teachers' Perceptions of Support

One particular aspect of the school context that bears influence on teachers' instruction is their perceived support from administration and fellow teachers (Chaplain 2008; Geving 2007; Lewis, 2007; Davidson 2009). In one study by Lewis (2007) secondary teachers who reported more support from their teacher teams in regard to standards-based mathematics practices were more successful in implemented those practices. The support from teacher teams showed solidarity in their goals and instructional practices. This type of support would be especially influential for novice teachers would report the pressures of

instructional decisions and workload as the major stressors (Forgasz & Leder 2006; Kyriacou & Kunc, 2007).

The administrators and teachers influence the school culture in which a classroom community of practice is situated and therefore has impacts on the actualization of the teachers' goals for his/her classroom (Skott, 2009). The work of Cobb, McClain, de Silva Lamberg, and Dean, (2003) further delineate the impact of school context on teaching and the authors state, "teaching is characterized as an activity that is distributed across a configuration of communities of practice within a school or district viewed as a lived organization" (pp. 22). Teachers must negotiate between the messages that are communicated from the "lived organization" and therefore if they feel support from their school community, they are more likely to have less tension to manage. This study measures teachers' perceptions of support in regards to mathematics instruction as a way to attend to possible tensions within the school community.

School Socioeconomic Status (SES)

Another aspect of school context that has been noted in research particular to mathematics education is the social economic status (SES) of the student body within a school (Lubienski, 2002; Lee, 2002). Research has well documented the positive relationship between SES and student achievement in mathematics (Ladson-Billings, 2006; Ma & Klinger, 2000; Ho, Caprora, Caprora, 2015, Zhang, 2009) with students of higher SES performing better on standardized tests. These differences in performance have driven on-going work in attempts to close the achievement gap (e.g., Lee & Burkam, 2002, Fryer & Levitt, 2004), also called the "opportunity gap" (Akiba, LeTendre, & Scribner, 2007);

however, more research is needed regarding the mathematics teaching practices related to differences in student learning.

Research examining mathematics teaching practices has mixed findings in regard to the opportunities for children from lower SES backgrounds (Diamond, 2007; Minor, Desimone, Phillips, & Spencer, 2015). Some research has reported that children from lower SES backgrounds receive more procedural instruction and fewer opportunities for higher-order thinking (Desimone & Long, 2010; Diamond, 2007; Means & Knapp, 1991) while more recent work states otherwise (Minor et al., 2015). Research by Desimone and Long (2010) investigated teaching practices within school contexts of varying SES and found that in their sample of kindergarten and first grade students of lower SES experienced more procedural instruction than their higher SES peers. However, this measure of procedural and conceptual instruction was measured using survey data and not classroom observation. Recent work by Minor and colleagues (2015) found that student of high and low SES backgrounds received the same portion of conceptual and procedural instruction, with procedural instruction being the majority for all subgroups. Again, this research used the same survey data source to measure instruction. This work will extend research regarding mathematics instruction and SES by using an observational measure to examine the quality of mathematics discourse within classrooms of varying SES. By attending to a specific reform-based practice such as discourse, opportunities for students from different SES backgrounds can be examined more closely.

Implications for Current Study

Amid the growing research on mathematical discourse, a distinct area that needs further attention is the exploration of how novice teachers utilize discourse and position students to participate in discussions and learning (Correnti, et. al., 2015). First of all, majority of research concerning novice teachers has focused on the socialization into the profession and the challenges of induction (Bullough et al. 1992; Kelchtermans & Ballet, 2004; Zeichner & Gore, 1990) and not the implementation of standards-based practices. This study specifically attends to the discourse practices of a novice teacher population to extend research during the induction years.

Furthermore, a majority of studies have not employed a systematic method for considering how students participate in classroom discussions, relying more on overall frequency counts or proportion of time collectively spent explaining or answering recall questions (Hiebert & Wearne, 1993; Kazemi & Stipek, 2001; Webb, et. al, 2008). The M-Scan (Berry, et al., 2010) provides a holistic way to categorize the type of mathematical discourse community that is constructed within a classroom as well as the quality of explanations from students. Taking a finer-grain size than a categorization of the discourse community, the Analyzing Teacher Move (ATM) framework provides a precise way to analyze the moves a teacher makes to orchestrate discussion in his/her classroom. The particular codes used to categorize the teacher moves provide specific information about the positioning of students and how the authority of the mathematics community is shared within the context of the classroom. This study will utilize both measures to extend theory by analyzing how patterns in teacher discourse moves, through the use of the ATM, contribute to classroom sociomathematical norms, as categorized by the M-Scan dimensions of

mathematical discourse community and explanation/justification. By using such a comprehensive way to analyze mathematical discourse, this study will provide insight to how novice teachers implement discourse moves and attend to their positioning of students.

Another area of research for which there is limited work and that this study will directly address is the influence of teachers' knowledge and beliefs on the structure of discourse within their classrooms (Resnick, Asterham, & Clarke, 2015). While research has well documented the consequences of effective discourse practices for students, the contexts that support teachers in their enactment of discourse practices are understudied. What are the experiences, knowledge, or belief systems that are likely to give a teacher the willingness and skill to orchestrate effective classroom discussions? By exploring the relationship between mathematical discourse, teachers' MKT, and teachers' beliefs, the reciprocal nature between practice, beliefs, and knowledge can be further examined as called for by Fives and Buehl (2012). Also, in addition to individual context, classroom and school factors are included to understand how they impact teachers' orchestration of mathematical discourse. These factors may be varied, but it is important to obtain as much information about the teachers' context as possible to allow for insight into what might influence the way teachers provide students opportunities in the classroom.

Research Questions

To investigate the intersection of novice elementary teachers' knowledge, beliefs, and school context as it relates to the discourse practices utilized in mathematics lessons, two primary research questions (presented as research questions 1 and 2 in the numbered list below) guided the quantitative phase of the study. First, the study investigated whether

teacher attributes and school contextual factors accounted for variation in the level of *mathematical discourse community* (MDC) between novice elementary teachers' mathematics lessons. By attending to the MDC within mathematics lessons, this study was able to examine the impact of teacher attributes and/or social context on the sociomathematical norms of the classroom. Similarly, the second goal of the quantitative phase was to determine if those same teacher attributes and contextual factors account for variation in students' *explanation and justification* (EJ), which is a more specific element of the classroom discourse, typically resulting from teacher probing.

Primarily, teachers' personal attributes (MKT, efficacy, and epistemological beliefs) were assumed to impact their approaches to teaching mathematics and therefore were hypothesized to account for variance in the discourse practices used by novice teachers. It was hypothesized that teacher attributes would account for a significant amount of variance in the level of MDC and EJ in mathematics lessons. First, MKT was hypothesized to strongly relate to the level of MDC and EJ within lessons due to research by Hill and colleagues (2008) that has shown that teachers with higher MKT are more likely to implement teaching practices that develop conceptual understanding. Students are directly positioned to develop a deeper conceptual understanding of a topic when teachers engage them with questions that allow students to explain their own thinking (Michaels, O'Connor, & Resnick, 2008).

Secondly, teacher with higher levels of personal mathematics teaching efficacy (PMTE) were hypothesized to create student-centered mathematical discourse communities and prompt more explanation and justification from students due to their feeling of effectiveness. Past research found that teacher who felt more efficacious were more likely to take risks in

their instruction (Tschannen-Moran, et al., 1998), and teachers are seen as taking risks when directing classroom discussion that involve more student contributions. Lastly, teachers with more sophisticated epistemological beliefs about the nature of mathematics were hypothesized to teach lesson with higher levels of MDC and EJ. Research in the area of epistemological beliefs has shown that teachers with more sophisticated beliefs about the mathematics discipline tended to express more constructivist beliefs about teaching (Cheng, Chan, Tang, & Cheng, 2009; Hasweh, 1996). Extending this connection, it seems that teachers with more sophisticated beliefs about the discipline of mathematics will be more likely to engage students in discussions that allow them to share their ideas and understandings, which are foundational constructivist practices.

In addition to teacher attributes, school contextual factors are influential in a teacher's implementation of practice (Skott, 2009). Past research has shown that students from lower SES backgrounds receive more procedural instruction (Desimone & Long, 2010; Diamond, 2007; Means & Knapp, 1991) and therefore it seems that opportunities for discussion and explanation may be different based on SES as well. As a result, it was hypothesized that teachers at schools with lower SES would implement lessons with lower levels of MDC and EJ. Another school contextual factor that was considered is the level of support teachers feel in regard to mathematics. It was hypothesized that TPSS would relate to the level of MDC in lessons in that MDC is a measure of overall participation of students. Research has shown that teachers who felt more support were more likely to engage in student-centered practice (Lewis (2007), and this is expected in the current study in terms of the solicitation of student ideas. However, the level of EJ is hypothesized to relate to teacher attributes and SES and not

TPSS. That is, teachers' TPSS will not be significantly related to the level of EJ in the mathematics lessons due to the strong influence of teachers' MKT on the navigation of student explanations. Lastly, grade level was entered in to the analysis as a control and was not hypothesized to impact the level of MDC nor EJ in mathematics lessons.

Following the quantitative analyses, the qualitative phase of this study provided a more in-depth examination of novice teachers' mathematics discussions to better understand the quantitative findings. Specific teacher attributes and/or school contextual factors that were significantly related to levels of EJ within the quantitative analysis were further investigated by analyzing how teachers (of the varying attributes and/or school contexts) orchestrated their classroom discussions. Two primary research questions guided the qualitative phase (presented as research questions 3 and 4 in the numbered list below). First, the qualitative portion of the study characterized the types of teacher moves used by teachers of varying attributes and school context, and secondly, it identified patterns in teacher moves that were similar across groups and differential between groups. Due to the fact that the quantitative findings are foundational to the qualitative phase of this study, the quantitative findings (Chapter 4) will be presented before the hypotheses for the qualitative phase are delineated (Chapter 5).

List of Research Questions:

1. What teacher attributes and school contextual factors account for variation in the level of mathematical discourse community (MDC) between novice elementary teachers' mathematics lessons?

- a. How does a teacher's **mathematical knowledge for teaching** account for variation in the level of mathematical discourse community?
 - b. Above and beyond teachers' mathematical knowledge for teaching, how does a **teacher's self-efficacy and epistemological beliefs about mathematics** account for variation in the level of mathematical discourse community?
 - c. Controlling for teachers attributes, how do school contextual factors, **school SES, teachers' perception of school support for mathematics (TPSS)**, and **grade level**, account for variance in the level of mathematical discourse community?
2. What teacher attributes and school contextual factors account for variation in the level of students' explanation and justification (EJ) between novice elementary teachers' mathematics lessons?
- a. How does a teacher's **mathematical knowledge for teaching** account for variation in the level of students' explanation and justification?
 - b. Above and beyond teachers' mathematical knowledge for teaching, how does a **teacher's self-efficacy and epistemological beliefs about mathematics** account for variation in the level of students' explanation and justification?
 - c. Controlling for teachers attributes, how do school contextual factors, **school SES, teachers' perception of school support for mathematics (TPSS)**, and **grade level**, account for variance in the level of students' explanation and justification?

3. How do novice teachers of varying attributes and in different school contexts utilize specific teacher moves to orchestrate classroom mathematics discussions?
4. In what ways do the patterns of teacher moves within mathematics discussions help to explain the quantitative results about teacher attributes and school context?

Chapter 3: Quantitative Methodology

Chapter 3 will provide an overview of the mixed methods design of the current study and then describe the quantitative phase of the study including data collection, measures, and analyses. As a result of the integral nature of the quantitative findings to the qualitative phase, it is important to present the quantitative results before detailing the qualitative methodology.

Research Design

The current study focuses on a subsample of participants, specifically the novice teachers in their second year of teaching, from the larger study. Examination of this subsample provides a better understanding of novice teachers' use of discourse practices during mathematics lessons and how those practices relate to knowledge, beliefs, and school/classroom context. This study utilized an explanatory, sequential mixed methods design that began with the collection and analyses of quantitative data followed by an in-depth analysis of qualitative data to explain quantitative findings. In the first, quantitative phase of the study, numerous teacher-level variables and school-context data were analyzed along with measures of discourse practices to identify statistically significant relationships. In the second phase, significant relationships between teacher-level and/or school contextual factors and discourse practices were further examined through a transcript study of purposefully sampled lessons to identify the patterns of teacher moves within the lessons. The quantitative phase will be outlined in detail in the following chapter, but first a description of the overall sample will be discussed.

Large Study Context

As a part of the larger NSF-funded study titled Accomplished Teachers of Mathematics and Science (Project ATOMS), teachers were recruited at the end of their first year of teaching for participation in the study in their second year of teaching. Propensity score matching (Fan & Nowell, 2011) was used to match teachers graduating from a STEM-focused elementary preparation program with other teachers graduating from other public, undergraduate teacher preparation programs in the same year. Teachers were matched based on SAT/ACT and high school grade point averages. The goal was to have a comparable sample based on college entrance characteristics. From this sampling technique, teachers were identified and recruited in two cohorts; 171 teachers participated in the study with 89 in the first cohort (2013-2014) and 82 in the second cohort (2014-2015). The average high school GPA was 4.25 and the average SAT/ACT score was 1098/22.2. Overall, the sample was 95% Female and 85% Caucasian which is representative of alumni of the preparation programs.

The participants attended a one-day summer session held at locations across the state; they selected a convenient location and date. The sessions included: training on how to use an instructional log (not a focus of this study); training on how to effectively video record instruction; and data collection on a variety of mathematics and science surveys and assessments. The training on video recording lessons prepared the participants for the larger study's requirement to record 3 mathematics and 3 science lessons at designated times throughout the year. The mathematics lesson recordings are at the center of this study's examination of teaching practice.

Quantitative Phase

The quantitative phase of this study examined how teachers' knowledge and beliefs and specific aspects of school context account for variance in the use of discourse practices in novice teachers' classrooms. This phase of the study pursued a more holistic view of the teacher and his/her practice by analyzing many facets of the teachers' attributes and school context. The following subsections will outline the subsample used in the quantitative phase and the measures used to represent teachers' knowledge, beliefs, and practice as well as school context.

Participants

Participants were 119 novice elementary teachers selected based on the presence of at least one recorded mathematics lesson for a teacher. Of this subsample, 9 teachers submitted 1 video, 18 teachers submitted two lessons, and 92 teachers submitted three or more lessons. Teachers with 1 or more recorded lessons were included in the present study because past research using the same observational measure found that the number of observations did not have a statistically significant influence on the M-Scan scores and that less than one percent of the variance in scores was attributable to number of observations (Walkowiak, 2010).

Teachers in the subsample were 98% Female and 85% were Caucasian. All teachers were in their second year of teaching at elementary schools, as dictated by the larger study, with an average age of 23. The elementary schools were located within the same southeastern state in the United States, but the schools were located across the state. Descriptive analysis of school-level information showed that 70% of teachers in the sample taught at schools that were classified as Title 1 schools and had over 50% of students receiving free and reduced

price lunch. Majority of the sample was above the national average, which was 49.6% of students eligible for free and reduced price lunch (U.S. Department of Education, 2013).

Measures

Mathematical Knowledge for Teaching (MKT) Measure in Number and Operation (N&O). The MKT-N&O measure was developed by members of the Learning Mathematics for Teaching Project (LMT) at the University of Michigan, and consists of 26 items designed to measure teachers' mathematical knowledge for teaching number and operations (Hill et al., 2004). This particular form of the MKT was selected due to the fact that majority of the content addressed in K-5 classrooms is focused on number and operations. The items on the MKT-N&O reflect actual teacher activities (e.g., solving mathematical content, assessing student solution methods, and explaining the conceptual underpinnings of common procedures such as the subtraction algorithm).

Through their validation efforts, Hill and colleagues (2004), provided evidence that the items measure common content knowledge (knowledge of the topic) and specialized content knowledge (knowledge needed to teach the content). Item response theory models (IRT) were used with the data and the IRT reliabilities for the different domains of the MKT-N&O were good to excellent, ranging from .71 to .84.

Participants completed the MKT-N&O via an online interface (the Teacher Knowledge Assessment System [TKAS] at the University of Michigan); they were allowed to use paper and pencil. Completed responses were scored by the TKAS and recorded in a master database as an IRT score.

Mathematics Teaching Efficacy Beliefs Instrument (MTEBI). The MTEBI measure (Enoch, Smith, & Huinker, 2000) is comprised of 21 items and uses a 5-point Likert scale (strongly disagree, disagree, uncertain, agree, and strongly agree) with “strongly agree” denoted by a 5. The measure consists of 13 items on the Personal Mathematics Teaching Efficacy (PMTE) subscale and 8 items on the Mathematics Teaching Outcome Expectancy subscale. Only the PMTE subscale was used in analysis due to alignment of PMTE with the theoretical underpinnings of the study. That is, PMTE is a teacher’s belief in his or her own ability to effectively teach mathematics. In the developers’ work, reliability analysis produced an alpha coefficient of 0.88 for the PMTE scale ($N = 324$) (Huinker & Enochs, 1995).

Participants completed the PMTE using an online interface. A raw score was calculated for the PMTE subscale, and then the scores were grand-mean centred to allow for a meaningful comparison of participants within the analysis. That is, a grand-mean score of 0 on the PMTE would indicate the mean score within the sample.

Mathematics Experiences and Conceptions Surveys (MECS). The MECS (Welder, Hodges, & Jong, 2012) was designed to measure pre-service and novice teachers’ attitudes, beliefs, and dispositions toward mathematics teaching and learning. This study used the beliefs subscale. The beliefs subscale included items that measured teachers’ beliefs about the discipline of mathematics. Items such as, “I believe mathematics involves making generalizations” aligns with the “nature of knowledge” dimension within the definition of epistemological beliefs (Muis, 2007). The beliefs subscale consisted of 10 items in which

teachers' responded to a 7-point Likert scale (strongly disagree, disagree, somewhat disagree, somewhat agree, agree, strongly agree) with a 7 as an indication of "strongly agree."

This study utilizes the MECS-Y1 which is designed for teachers in their first through third year of teaching. The Rasch Rating Scale Model was used in the validation of the MECS (Jong, et al., 2015), and subscales were analyzed jointly as the construct of "conceptions" and also separately. As a collective Rasch analysis, 60.9% of variance was explained by the measure and reliability estimates were .87 for person and .99 for items.

The beliefs subscale within the MECS contains 10 items that attend to different aspects of teachers' beliefs about nature of mathematics and the value of mathematics (epistemology). Reliability was high for this subscale ($\alpha = .78$) (Jong et al., 2015). However, due to discernment between epistemological beliefs about the nature of knowledge and epistemic value (Muis, 2007) the researcher conducted an exploratory factor analysis (EFA) using the 10 items on the beliefs scale to investigate possible indications that the items were measuring distinct components of beliefs. Table 3.1 shows the three factors that emerged from the EFA. The first factor "Nature" included items that focused on nature of the mathematics discipline. The second factor was specifically about the use of calculations in mathematics (Calculations). The last factor attended to teachers' value of mathematics (Value) and aligned with the field's categorization of epistemic value. The factors were used separately in the quantitative analyses to allow for specificity in the definition of beliefs. From this point forward, when referring to teachers' collective notion of epistemological beliefs, TB, will be used. When referring to a specific component of epistemological beliefs

as measured by these distinct subscales, the specific subscale will be used by name (e.g., Nature).

Participants completed the MECS using an online interface. A raw score was calculated for the *Nature*, *Calculations*, and *Value* subscales and then the scores were grand-mean centred to allow for a meaningful 0 within the analysis. That is, a grand-mean score of 0 on the Nature subscale would indicate the average score within the sample.

Table 3.1

Epistemological belief factors that emerged from EFA of beliefs scale

Factor Name	Description	Sample Item	α
Nature	Teachers' beliefs about the nature of mathematics	Doing mathematics involves analyzing multiple strategies for solving problems.	.70
Calculations	Teachers' beliefs about the nature of calculations	Mathematics is mostly about performing calculations.	.60
Value	Teachers' value of mathematics	Knowing mathematics can improve a person's life	.80

Teachers' perceptions of school level support for mathematics instruction

(TPSS). Participants in the larger study were also required to report on perceptions of their school. Participants responded the question stem, "In your opinion, how great a problem is each of the following for math instruction?" to rate their feelings of the following items:

Inadequate funds for purchasing math equipment and supplies, Inadequate materials for individualizing math instruction, Lack of opportunities for math teachers to share ideas,

Inadequate math-related professional development opportunities, Interruptions of math instruction for announcements, assemblies, and other school activities, and large class sizes.

For the purpose of this study an index of support rating was created from these items to provide a measure of the level of support the teacher felt in regards to mathematics instruction. The item response options (a serious problem, somewhat of a problem, and not a significant problem) were given a score of 1-3, respectively, and total score was calculated.

School Contextual Variables. A measure of the school's SES was created using the percentage of students receiving free or reduced price lunch (FRPL). The grade level for each teacher was recoded to create a grade band variable. Kindergarten, first, second grades were considered primary grades, while third, fourth, and fifth grades were considered intermediate grades.

Mathematics Scan (M-Scan) Observational Measure. The M-Scan is an observational protocol that measures the presence and extent of standards-based mathematics in elementary classrooms (Berry et al., 2013). The measure consists of ten dimensions of standards-based mathematics including mathematical accuracy; structure of the lesson; teacher's use of multiple representations; students' use of multiple representations; students' use of tools, cognitive demand; mathematical discourse community; explanation and justification; problem-solving; and connections and applications. A trained observer rates a mathematics lessons on these dimensions using a 7-point scale that is divided into three levels: low (1-2); medium (3-5); and high (6-7).

M-Scan training involved face-to-face explicit explanation of the dimensions and activities to help conceptualize their meanings (e.g., tasks sorts and questioning types).

Following the instructional session, trainees would code a common video and convene to discuss their ratings in comparison to a master coder. This process was repeated for a second video. Next, trainees would code 4-6 videos, and then meet with the master coder to compare scores. The trainee would need an 80% match for each dimension between his/her codes and master coder. If 80% reliability for each dimension was not met, training materials were revisited to clarify concepts and scoring guidelines. An additional set of 4 videos was assigned for the trainee to code and compare with master coder. Once reliability was established, coders individually coded and met back every other week for a drift check. Drift checks involved the coding of a common video in which coders would complete individually and then meet to discuss scores. During discussion, consensus was met. If a coder was off from the consensus, training materials were revisited. This training process was utilized within the study as well.

There are specific descriptions for each level that are thoroughly defined in the coding protocol (See Appendix A). There are also indicators within the overall dimension. For example, the *Mathematical Discourse Community* dimension consists of three indicators: teacher's role in discourse, sense of mathematics community through student talk, and questions. The overall score for the dimension is calculated by averaging the score (1-7) on each indicator. Therefore, if a teacher scored at a level 6 on both *teacher's role in discourse* and *questions* but scored a 4 on sense of *mathematics community through student talk*, 5 would be the overall score.

Validity work with the M-Scan (Walkowiak, Berry, Meyer, Rimm-Kaufman, & Ottmar, 2014) has demonstrated content validity through expert review of the dimensions

and alignment with standards-based practices as defined in the field (NCTM, 2000; 2007). Also, response processes of coders were analyzed and 88% of coders interpreted the dimension and indicator descriptors as intended. Lastly, as a form of convergent and discriminant validity, lessons were rated using the M-Scan and existing observational protocols, the *Classroom Assessment Scoring System* (CLASS; Pianta, La Paro & Hamre, 2008) and the *Reformed Teaching Observational Protocol* (RTOP; Piburn et al., 2000), and bivariate correlations were examined. Convergence of problem-solving, cognitive demand, and mathematical discourse community dimensions with the RTOP provide evidence to support that the conceptualizing of constructs is supported in other work. For example, the MDC dimension converged with the RTOP, with a significant correlation of .78. However, in other dimensions, the M-Scan provides a uniqueness that is demonstrated in the divergence from the other measures.

This study specifically examines Mathematics Discourse Community (MDC), and Explanation and Justification (EJ) dimensions of the M-Scan. The indicators for MDC are *teacher's role in discourse, sense of mathematics community through student talk, and questions*. The indicators for EJ include *presence of explanation/justification* and *depth of explanation/justification*.

Analysis

The first step in the quantitative analyses of this study was to measure mathematics teaching practices, specifically mathematics discourse, present in each lesson using the M-Scan observational measure. A team of five graduate students were trained on the M-Scan observational protocol during a 12-hour training facilitated by a co-developer of the measure

that followed the training outlined in the M-Scan measures section. Coders were scheduled to code between 25 and 60 lessons each.

In the next step of the quantitative phase, a series of multilevel means-as-outcomes analyses were conducted using SAS software to examine the proportion of variance in the classroom discourse dimensions that are explained by teacher attributes and school contextual factors. Figure 3.1 illustrates the nested nature of the data. In the multilevel modeling framework, individual variability is represented through a 2-level hierarchical model (Hawkins, Guo, Hill, Battin-Pearson, & Abbott, 2001). At Level 1, each teachers' variability in MDC or EJ is represented by an intercept and slope that become the outcome variables in a Level 2 model in which they may depend on teacher level factors (e.g., MKT, Nature, and PMTE). By examining the variability in MDC and EJ across multiple lessons, multilevel modeling is a powerful and flexible approach compared to techniques, such as multiple regression (Schulenberg & Maggs, 2001). Also, because estimates of both between-person and within-person variability are possible with multilevel models (Lee & Bryk, 1989) this approach allows for conclusions regarding both levels. Additionally, multilevel modeling uses all available data from each participant and can effectively manage unequal data (Raudenbush & Bryk, 2002). This model has its advantages due to the range in number of lessons available in the current study.

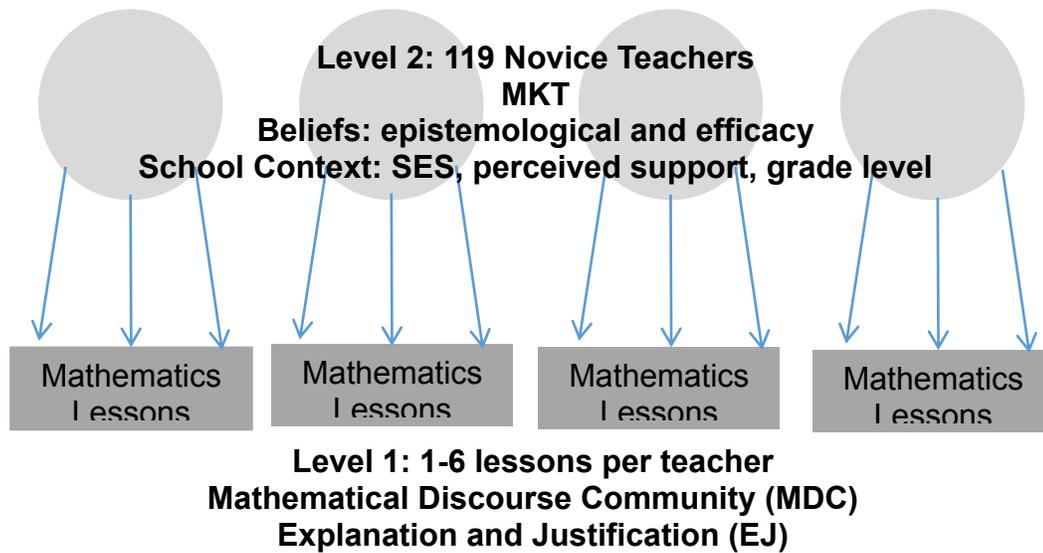


Figure 3.1: *Visual of the nested nature of the multi-level data*

MDC and EJ were entered into the model as Level-1 variables. Teacher attributes in terms of knowledge and beliefs were entered as Level-2 variables because they describe characteristics of the teacher. Teachers' scores on the MKT assessment served as a measure of their knowledge. The three factors of the MECS beliefs scale, Nature, Calculations, and Value, were entered as measures of teachers' beliefs along with PMTE as a measure of teachers' mathematics teaching efficacy. Also, TPSS was considered a Level-2 variable due to the fact that it represents teachers' perceptions of their school support. In addition to

TPSS, grade level and FRPL, as measure of school-level SES, were entered as Level-2 variables. Although the school-level SES is a school-level variable, in the analyses it was represented at the teacher level due to the fact that between-school comparisons are not a part of the study and there were not multiple teachers at the same school.

First, a fully unconditional model/null model (Raudenbush & Bryk, 2002) was conducted to determine the variability within teachers (Level 1) and the variability between teachers (Level 2) on the variables of MDC and EJ. This analysis provided the percentage of variance between teachers that served as a frame of reference for the next models; that is, if a model explained 30% of the variance at Level 2 then this would be 30% of whatever percent the fully unconditional model reported. The null models for each dependent variable, MDC and EJ, were estimated with the following equations:

Model 1	Level 1: $MDC_{it} = \beta_{0it} + r_{it}$	Level 1: $EJ_{it} = \beta_{0it} + r_{it}$
	Level 2: $\beta_{0i} = \gamma_{00} + \mu_{0i}$	Level 2: $\beta_{0i} = \gamma_{00} + \mu_{0i}$

From this output the level of interdependence of the dependent variables was computed with $\tau_{00}/(\tau_{00} + \sigma^2)$ as well as a chi-square statistic to determine that the between teacher variance was significantly different from zero.

Next, for each outcome variable, MDC and EJ, a series of Means-as-outcomes regression analyses were conducted to examine the main effect of teacher attributes (i.e., MKT, TB, PMTE) and school context (FRPL, grade-band, TPSS) on teachers' MDC and EJ. Teacher attribute variables were examined to address research question 1: *What teacher attributes account for the variation in the mathematical discourse in novice elementary teachers' mathematics lessons?* The Means-as-outcome regressions were conducted in a

step-wise format to better understand the influence of each independent variable on the dependent variables. First, only MKT was entered into Model 2. In the field, teachers' MKT has been tied to student achievement (Hill et al., 2007) and instructional choices (Hill et al., 2008) and therefore bears a strong theoretical significance on the types of discourse that may occur in mathematics lessons. This theoretical underpinning is the reason for starting with MKT as a predictor of the level of MDC and EJ in teachers' lessons.

Model 2 Level 1: $MDC_{it}/EJ_{it} = \beta_{0it} + r_{it}$
 Level 2: $\beta_{0i} = \gamma_{00} + \gamma_{01} (\text{MKT}) + \mu_{0i}$

Next, Model 3 included MKT and measures of teachers' beliefs including the Nature, calculations, epistemic value, and PMTE:

Model 3 Level 1: $MDC_{it}/EJ_{it} = \beta_{0it} + r_{it}$
 Level 2: $\beta_{0i} = \gamma_{00} + \gamma_{01} (\text{MKT}) + \gamma_{02} (\text{PMTE}) + \gamma_{03} (\text{Nature}) + \gamma_{04} (\text{Calculations}) + \gamma_{05} (\text{Value}) + \mu_{0i}$

Lastly, school contextual variables including percent FRPL, grade band, and TPSS were added in Model 4 to address research question 2: *Controlling for teacher attributes, how do contextual factors account for variance in the level of mathematical discourse community and level of student explanation and justification?*

Model 4 Level 1: $MDC_{it}/EJ_{it} = \beta_{0it} + r_{it}$
 Level 2: $\beta_{0i} = \gamma_{00} + \gamma_{01} (\text{MKT}) + \gamma_{02} (\text{PMTE}) + \gamma_{03} (\text{Nature}) + \gamma_{04} (\text{Calculations}) + \gamma_{05} (\text{Value}) + \gamma_{06} (\text{FRPL}) + \gamma_{07} (\text{Gradeband}) + \gamma_{08} (\text{TPSS}) + \mu_{0i}$

The percentage of total variance explained for each model was calculated for each independent variable (i.e., MDC and EJ) using the following formula (Kenny et al., 2006) where UCmodel represents the current model being used:

$$1 - \frac{(\tau_{00UCmodel} + \sigma^2_{UCmodel})}{(\tau_{00NULL} + \sigma^2_{NULL})}$$

The percentage of variance explained between teachers by the Level-2 predictors was be calculated with the formula $(\tau_{00null\ model} - \tau_{00UCmodel}) / \tau_{00null\ model}$ for each model (Hofmann et al., 2000).

Chapter 4: Quantitative Results

In the quantitative phase of the study, a series of multilevel regression analyses were conducted to investigate teacher attribute and school contextual factors that accounted for variance in teachers' MDC and EJ within lessons. Before examining the relationship between the independent variables (teacher attributes and school contextual factors) and the outcomes of MDC and EJ, descriptive statistics were analyzed (reported in Table 4.1), and preliminary analyses were completed to ensure that there was sufficient variability at Level 2 (MDC and EJ) to warrant continuation with analyses (e.g., Nezlek, 2001; Raudenbush & Bryk, 2002). Next, a series of multilevel models were fit to determine the statistical significance of the relationship between the independent and outcome variables. In the Level 1, the intercept, B_{0it} , is defined by the expected level of MDC or EJ for an individual teacher. The error term, r_{it} , represents a unique effect associated with an individual (i.e., how much that individual fluctuates or varies over time). The individual intercepts (B_{0i}) become the outcome variables in the Level 2 equations, where the average level of MDC or EJ for the sample at baseline (i.e., when $MKT=0$) is represented by the γ_{00} . The extent to which people vary from the sample average of MDC or EJ is represented by μ_{0i} .

The results will be presented in terms of the outcome variables. That is, first the models with MDC as the outcome variable will be reported and then the models for EJ as the outcome variable. Research question 1 will be addressed within the MDC section and research question 2 will be addressed in the EJ section. In advance of reporting the findings from the multilevel analyses, descriptive statistics will be presented and summarized.

Descriptive Statistics-Independent Variables

Table 4.1 describes the analytic sample in terms of teacher attribute and school contextual data (independent variables). The overall sample was 119 novice teachers, but there was a small portion of missing data for MKT ($n = 2$), beliefs measures ($n = 2$), and school contextual data ($n = 5$). There were no significant differences between the samples; therefore, no participants were excluded due to missing data for one of the independent variables.

As shown in Table 4.1 Teachers' MKT were standardized and a Z-score was utilized in all analyses. That is, a teacher with an MKT score of 0 represents the average MKT of this sample of novice teachers. The remaining independent variables were grand-mean centered, but are presented as raw scores in the descriptive table to provide a more transparent representation of the sample. This sample of teachers reported a higher PMTE ($M = 54.58$) than the average defined by the scale of the measure ($M = 39$), but this has also shown to be typical of pre-service and novice teachers in similar institutional settings (e.g., Bates, Latham, & Kim, 2011; Moseley & Utley, 2006). Teachers' beliefs as measured by the *Nature*, *Calculations*, and *Value* subscales varied in relation to the mean of the scales used. Teachers' reported *Nature* scores ($M = 12.35$) were aligned with the scale's average ($M=12$), while reported *Calculation* and *Value* scores ($M = 18.86$; $M = 15.73$) were higher than the scales' representative averages, which were 16 and 12, respectively.

Table 4.1
Descriptive Statistics of Level 2 Independent Variables

	M (SD)	Minimum	Maximum
Teacher Attributes			
Mathematical Knowledge for Teaching (MKT) z-score	0.0 (1.0)	-2.07	2.08
Personal Mathematics Teaching Efficacy (PMTE)	54.58 (5.169)	44	65
Beliefs about the nature of mathematics (Nature)	12.35 (2.15)	7.0	18.0
Beliefs about the use of calculations (Calculations)	18.86 (1.92)	14.0	23.0
Epistemic value of mathematics (Value)	15.73 (1.73)	10.0	18.0
School Context			
% Free and Reduced Price Lunch (FRPL)	62 (23)	.06	1.0
Perceived school support of mathematics (TPSS)	14.73 (2.68)	8	18
Grade Level (K-5) 0=K	2.42 (1.49)	0	5
Primary Grades (K-2) <i>n (%)</i>	68 (57%)		
Intermediate Grades (3-5) <i>n (%)</i>	51 (43%)		

Descriptive Statistics-Dependent, Outcome Variables

In addition to descriptive statistics for the independent variables, Table 4.2 presents descriptive statistics for the outcome variables, MDC and EJ, that were included at level 1 of the multilevel analyses. Also, descriptive information about the length of lessons in which the MDC and EJ ratings were coded are presented. The length of the lessons is reported in terms of the type of instruction (independent, pair/small group, whole group) that was present during the lesson. The MDC (M=3.78) of the lessons within the sample is slightly higher

than the average score on the M-Scan dimension scale (M=3.5). On the other hand, the EJ (M=3.18) of the sample is slightly lower than the scale's average (M=3.5). The descriptive data presented in Table X are not nested within teacher and therefore represent a general sense of all the lessons included in the quantitative analyses.

Table 4.2
Descriptive Statistics for Level 1 Outcome Variables and Lesson Length

	M (SD)	Minimum	Maximum
MDC	3.78 (1.18)	1	7
EJ	3.18 (1.50)	1	7
Lesson Lengths (minutes)	39.27 (16.62)	5	100
Independent Work	5.44 (9.30)	.00	71.00
Pair/Small group Work	12.05 (15.45)	.00	91.00
Whole group	21.85 (13.37)	.00	73.00

The subsequent sections report the results of the multilevel analyses that nested the lessons within teacher and examined the relationship of MDC and EJ with teacher attribute and school contextual factors. All independent variables, except for grade-band, were grand-mean centered so that a value of 0 represented the average of this novice teacher population. Grade-band was dichotomously scored with 0 representing grades K-2 and 1 representing grades 3-5. First the null or unconditional model for MDC and EJ will be presented. Then MDC will be presented and subsequently EJ will follow with details of the analytical results.

Fully Unconditional Models/Null Models

Preliminary analyses were completed to ensure that there was sufficient variability at Level 2 for MDC and EJ to warrant continuation with analyses (e.g., Nezlek, 2001; Raudenbush & Bryk, 2002). This type of preliminary analysis is termed a fully unconditional model or null model, in which no term other than the intercept is included at any level

(Curran, 2000; Nezlek, 2001). Results from the full unconditional or null model indicated that 37% of the variability in the level of MDC was between teacher ($\tau_{00} = .51, z=4.57, p<.001$) and 63% was within lessons for an individual teacher ($\sigma^2=.88, z=10.50, p<.001$). The fully unconditional model for EJ indicated that 33% of the variability in the level of EJ was between teacher ($\tau_{00} = .75, z=4.25, p<.001$) and 67% was within lessons for an individual teacher ($\sigma^2=1.51, z=10.46, p<.001$). These results indicated sufficient variability for further analyses. These results will be reported for MDC and then for EJ.

Mathematical Discourse Community (MDC)

To determine if the defined teacher attributes and/or school contextual factors accounted for statistical variance between teachers in their MDC scores, a series of Means-as-outcomes regression analyses were conducted. Table 4.3 contains the results of the analyses. The first model presents the null model for MDC as an outcome variable. The null model (Model 1) shows that the average MDC without controlling for any other variable was 3.78, which is slightly higher than the scale's average (3.5). This average score was the point of reference when other variables were entered into the models. The following sections reflect the order in which independent variables were entered into the models: 1) MKT 2) Beliefs (PMTE and epistemological), and 3) school contextual factors (FRPL, TPSS, grade-band).

When MKT was entered into the model by itself (Model 2), it was not a significant predictor of the average level of MDC within teachers' lessons. However, when the TB variables and PMTE were entered into the model, The *Nature* subscale was a significant predictor of the level of MDC in teachers' mathematics lessons ($p<.05$). That is, controlling

for teachers' MKT and PMTE, teachers with more sophisticated/standards-based beliefs about the nature of mathematics also tended to have higher levels of MDC within their lessons on average. For each scale point increase in the *Nature* score, the MDC score on average would increase .08 points. In comparison to the null model, Model 3 accounted for 24% of 37% of the variance between teachers on MDC.

In the next step (Model 4), school context variables were added. When controlling for all other variables, *Nature* ($p < .05$), FRPL ($p < .05$), and TPSS ($p < .04$) accounted for a significant amount of the variance between teachers in their scores on MDC. When controlling for the other variables, for each unit increase in a teachers' *Nature* score the average MDC score would also increase by .13 units while for each unit increase in the FRPL percentage there would be an average decrease of .80 units of MDC. Finally, for each unit increase in TPSS you would expect a .06 unit increase in MDC. Overall, Model 4 accounts for 24% of the 37% of variance between teachers on their MDC scores. This model accounts for the same amount of variance as Model 3, but with more variables serving as controls, this model is more robust.

Table 4.3
Estimated Effects of Teacher Attributes and School Context on the Level of Mathematical Discourse Community (MDC)

	Model 1 DF=118 (SE)	Model 2 DF=115 (SE)	Model 3 DF=109 (SE)	Model 4 DF=100 (SE)
Fixed Effects				
MDC, β_0 Intercept, γ_{00}	3.78** (.08)	3.79** (.08)	3.79** (.08)	3.79** (.11)
Teacher Attributes				
MKT, γ_{01}		0.16 (.08)	.11 (.09)	.14 (.09)
PMTE, γ_{02}			-.001 (.02)	.01 (.02)
Nature, γ_{03}			.08* (.04)	.13* (.04)
Calculations, γ_{04}			.03 (.05)	.03 (.04)
Value, γ_{05}			.03 (.05)	.08 (.05)
Teaching Context				
FRPL, γ_{06}				-.80* (.38)
Grade band, γ_{07}				-.01 (.18)
TPSS, γ_{08}				.06* (.03)
Random Effects				
MDC (τ_{00})	.51** (.11)	.48** (.11)	.47** (.11)	.38** (.10)
Within-teacher variation (σ^2)	.88** (.08)	.89** (.09)	.89** (.09)	.89** (.09)

Note. ** $p < .01$ * $p < .05$

Explanation & Justification (EJ)

Subsequently, models were fit to examine the relationships between all dependent variables and EJ. Table 4.4 contains the results of the analyses. The first model presents the null model for EJ as an outcome variable. The null model (Model 1) shows that the average EJ for this population of novice teachers' was 3.19, which is slightly lower than the scale's average (3.5). This average EJ score reflects the average without controlling for any other variables, and was the point of reference when other variables were entered into the models.

The following sections reflect the order in which independent variables were entered into the models: 1) MKT 2) Beliefs (PMTE and TB), and 3) school contextual factors (FRPL, TPSS, grade-band).

First, MKT was entered into the model by itself and it was a significant predictor of EJ ($p < .05$). In the next step, controlling for PMTE and the EB subscales, MKT remained a significant predictor of the level of EJ ($p = .05$) and the *Nature* subscale was significant as well ($p < .05$). That is, for each unit increase in MKT score, EJ was expected to increase .22 units. Also, teachers with more sophisticated/standards-based beliefs about the nature of mathematics tended to have higher levels of EJ within their lessons on average, and for each scale point increase in the Nature score, the EJ score on average would increase .13 points. In comparison to the null model, this model accounted for 14% of 33% of the variance between teachers on their EJ scores.

In the next step, school context variables were added. When controlling for all other variables, MKT ($p < .05$), and *Nature* ($p < .05$) remained significant predictors of EJ, while no school contextual variables were significantly related to the level of EJ. When controlling for the other variables, for each unit increase in a teachers' MKT score you would expect the average EJ score to be .24 units higher. Also, you would expect for each unit increase in the Nature score, an increase of .17 for the unit of EJ. This inclusive model accounted for 23% of the variance between teachers on EJ scores.

Table 4.4
Estimated Effects of Teacher Attributes and School Context on the Level of Explanation and Justification (EJ)

	Model 1 DF=118 (SE)	Model 2 DF=115 (SE)	Model 3 DF=109 (SE)	Model 4 DF=101 (SE)
Fixed Effects				
EJ, β_0				
Intercept, γ_{00}	3.19** (.11)	3.20** (.10)	3.21** (.10)	3.16** (.14)
Teacher Attributes				
MKT, γ_{01}		.27* (.10)	.22* (.11)	.24* (.15)
PMTE, γ_{02}			-.01 (.02)	-.004 (.02)
Nature, γ_{03}			.13* (.05)	.17* (.05)
Calculations, γ_{04}			.04 (.06)	.05 (.05)
Value, γ_{05}			-.01 (.06)	.05 (.06)
Teaching Context				
FRPL, γ_{06}				-.76 (.48)
Grade band, γ_{07}				.09 (.04)
TPSS, γ_{08}				.07 (.04)
Random Effects				
EJ (τ_{00})	.75** (.18)	.70** (.17)	.65** (.17)	.58** (.17)
Within Teacher variance (σ^2)	1.51** (.14)	1.50** (.15)	1.53** (.15)	1.50** (.15)

Note. ** $p < .01$ * $p < .05$

Chapter 5: Qualitative Methodology

Introduction

The qualitative phase of this study was designed to provide a more in-depth examination of novice teachers' mathematics discussions to better understand how different attributes and school contextual factors might influence how a teacher guides students to participate in classroom discussions. This portion of the study characterized the types of teacher moves used by teachers of varying attributes and school context, and secondly, it identified patterns in teacher moves that were similar across groups and differential between groups.

Based on the quantitative findings that teachers' MKT and *Nature* were significant predictors of the level of EJ within mathematics lessons, when analyzing mathematic discussions it was hypothesized that patterns in teacher moves would be distinct based on these attributes. More specifically it was hypothesized that teachers with high levels of MKT would utilize more open-ended prompts creating a more student-centered discussion. This hypothesis was based on past research that found teachers with a stronger knowledge base prompted students for their ideas more often (Hill et. al., 2008). Also, it was hypothesized that teachers with more sophisticated beliefs about the nature of mathematics would use less literal questioning which is associated with more static beliefs about knowledge (Spangler, 1992). Overall, teachers with higher MKT and higher *Nature* scores were hypothesized to position their students to be more involved in classroom discussion through explaining their ideas and not just restating known information.

Sampling Method and Participants

The quantitative phase of this study indicated that there was significant variation between teachers in regard to the level of MDC and EJ within their mathematics lessons. Furthermore, teachers' beliefs about the nature of mathematics, percent of students eligible for free or reduced price lunch (FRPL), and the teachers' perceived school-level support accounted for a significant amount of variation in level of MDC within teachers' lessons. In terms of the level of EJ, teachers' MKT and beliefs about nature of mathematics were significant predictors. Based on these findings, a purposeful sample was constructed to further investigate the variation in discourse by analyzing classroom discussions at a finer grain. Due to the theoretical alignment of the ATM framework and EJ dimension of the M-Scan, MKT was selected as the key sampling variable because of the significant main effect between MKT and EJ. Also, this selection was made based on the theoretical support for MKT as an influential factor in teachers' instructional choices (Hill et. al., 2008) and that it was the teacher attribute with the largest effect size ($\gamma_{01} = .23$, $p < .05$). Furthermore, with the teacher at the center of the analysis, a teacher attribute should be the driving force behind sampling and not a school-level characteristic.

A subsample of teachers from the study's overall participants was selected by creating a list of teachers with MKT scores that were above ($n = 9$) and below ($n = 10$) one standard deviation of the average of the study's participants (Z-score). Only participants with 3 or more lessons were included in the subsample to ensure the most robust sample for the qualitative analysis. From this list, 7 teachers were selected above one standard deviation and 7 teachers were selected that were below one standard deviation. Of those 14 teachers

selected, teachers were selected that had varying levels of beliefs about the nature of mathematics (*Nature*) and with varying levels of FRPL. This attention to beliefs and FRPL allowed for other significant main effects to be explored in relation to the qualitative analysis of the classroom discussions. It is important to note that while FRPL had the largest effect size ($\gamma_{06} = -.80, p < .05$) with MDC, the qualitative analysis only examines the classroom teacher-led discussions and therefore does not attend to all elements captured within the MDC dimension (e.g. student-to-student talk). However, noting the level of FRPL will allow for any patterns to be presented within this additional context. Table 5.1 shows the participants for the qualitative phase.

Table 5.1
Subsample for Qualitative Phase

Teacher	MKT Z-score	Nature Raw Score	Nature Z-Score	School FRPL (%)
Lindsey	2.07	11	-.63	43
Mikel	1.45	15	1.23	71
Tyler	1.45	15	1.23	45
Mona	1.45	10	-1.09	81
Jodi	1.03	13	.30	12
Ashley	1.03	10	-1.09	59
Mason	1.03	14	.77	97
Keri	-1.06	10	-1.09	87
Ryan	-1.35	16	1.69	95
Stacey	-1.36	13	.30	74
Keira	-1.36	15	1.23	86
Becca	-1.53	11	-.63	57
Jennings	-1.53	13	.30	43
Dana	-2.07	14	.77	78

Data Collection

In order to examine the patterns within the selected teachers' mathematics discussions, the recorded mathematics lessons of this subsample of teachers were viewed and specific timestamps were recorded to denote when the teacher engaged with her students in a whole-group or small-group math discussion. These sections of the recorded lessons were then transcribed verbatim with indications of when the teacher was speaking and when student/s was/were speaking. The researcher was blinded to the quantitative descriptors (e.g., MKT, TB) of each teacher in the qualitative subsample to reduce bias during coding. The researcher then systematically coded each teacher utterance using an a-priori coding scheme as outlined in the following section. A total of 42 transcripts were coded with most participants having three lessons. Two participants only had 2 codeable lessons; one teacher had a lesson with no whole-group or small-group discussion, and a second teacher's lesson was not codeable due to sound issues.

Analytic Process

To analyze the teacher moves within a mathematics discussion, the Analyzing Teacher Moves Guide (ATM) was used (Stein et al., 2015) as a-priori codes. The ATM is a tool for examining how a teacher directs or orchestrates discussions in the classroom by categorizing each question or comment a teacher makes in the discussion. Furthermore, each question or comment from the teacher is considered in the context in which it is used. This means that when coding a teacher's question or comment, the coder must consider what was said before and after to determine the categorization of the code. The ATM does not merely

serve as a categorization of moves but instead is a targeted method for studying the interactions within a classroom in their context (Scherrer, 2013).

Coding of teacher moves was done through “systematic observation” (Mercer, 2010) using the ATM guide. Each teacher move was denoted on the line of the transcript in which it occurred. A teacher *move* is any utterance a teacher makes. A teacher *turn* is a segment of the discussion in which the teacher is talking and that ends when a student begins talking; each turn in the conversation may include one teacher move or multiple moves.

Of the forty-two transcripts (which include whole-group and small-group discussion led by the teacher), 3 transcripts were initially read and coded by two raters to establish reliability of the interpretation of the ATM codes. The two raters had 80% agreement, an acceptable level of agreement, before the lead researcher continued with coding the remaining transcripts. In the cases of discrepancies between the two raters, consensus was reached through discussion. Throughout the coding of the transcripts, the lead researcher and the additional rater met after the coding of 5-6 transcripts and coded a common transcript to ensure that reliability was being maintained for a total of 6 common transcripts. A more detailed explanation of the ATM guide will now be presented to provide clarity on the coding process.

Coding with ATM Guide

Teacher moves are broadly categorized as initiating moves, which are moves a teacher uses to start a discussion, and rejoinder moves, which are moves that show a teacher is hearing what a student has said (Correnti et al., 2015). The ATM coding guide (Stein et al.,

2015) was used to define the moves in the following section and Table 5.2 provides a synthesis of the move categories.

Initiating Moves. Initiating moves are further delineated to specific moves termed *launch*, *literal*, *re-initiate*, *redirect*, *think aloud*, and *provides information*. *Launch* is a move that is an open-ended question used to invite student thinking. Examples include “How might you solve this problem?” or “How might you classify this shape?”. The question must invite multiple answers that require synthesis on the part of the student and not just a fact or recall of information. If the question asks for retrieval of a specific answer that is factual knowledge, this would be coded as a *Literal* move. In contrast to the open-ended nature of a *Launch* move, a *Literal* move would be “How many sides does a triangle have?” which has one correct answer. A *Re-initiate* move is when the teacher repeats the same or similar question that was just asked prior. If a teacher asked “How might you solve this problem?” and then allows a three second wait time and asks the question again, the second utterance would be classified as *Re-initiate*. This differentiation shows the added value of the ATM coding guide, because if a researcher were just categorizing questions this question would add to the frequency of open-ended type questions without attention to its situated nature within the conversation.

Another move a teacher can make within the Initiating category is a *Redirect* move. This type of move is used to ask a question to direct student thinking in a different direction because the initial question was not fully answered. It is not simply a restatement of the previous questions, as a *Re-initiate* move, but offers a certain level of structure or additional information. For example, if a teacher asks, “How can we represent this addition problem?”

and a student describes the standard algorithm, the teacher may want to probe their understanding of the concept with base ten blocks and therefore may redirect by asking, “How can you represent the problem using the base ten blocks at your table?”

Two moves within the Initiating category that are commentary from the teacher and not questions are *Think Aloud* and *Provides Information*. *Think Aloud* is a move used when the teacher talks about how he/she is thinking about a problem. The teacher talks through the process and draws attention to the strategies and decisions he/she makes. *Provides Information* is when the teacher reveals or provides relevant information for the current task. This code is used when a teacher tells the students a specific fact or procedure. For example, if students are solving a problem involving the interior angles of a triangle and the teacher says, “Remember that the sum of the angles in a triangle is 180° ” this utterance would be coded as *Provides Information*.

Rejoining Moves. Rejoinder moves are *Terminal*, *Lot*, *Repeats*, *Uptake*, *Uptake-Literal*, *Push-Back*, *Collecting*, and *Connection*. If a teacher provides an evaluation of a student’s response, much like the IRE pattern of discourse (Cohen, 1989), this is a *Terminal move*. The student’s response is discontinued with this type of move in the sense that the teacher is stating, “No, wrong” or providing a statement of approval such as “I like that.” A move is coded as *Lot* if the teacher states that the question or idea will be addressed at a later time.

Repeats is when the teacher echoes a student’s response. If a teacher then uses that response to further the discussion, this is classified as an *Uptake* move. *Uptake* is meant to extend the conversation through an open-ended question such as “You said the answer is too

large; how did you determine that?” If the teacher uses a student’s response to ask a literal question the move is defined as *Uptake-Literal*. A *Push-back* move is also a type of uptake that uses a student’s response but in which the teacher challenges the response to have the student rethink or defend their idea. If a student describes a new method they used to solve a problem and the teacher questions, “Will that always work?” the teacher is acknowledging the student’s idea but challenging him/her to defend the generalizability of the method; this would be coded as *Push-back*.

Two additional Rejoinder moves include *Collecting* and *Connection*. *Collecting* is designated to capture when a teacher solicits multiple ideas from students, much like a brainstorming session, without the intended goal of extending or elaborating on student ideas (*Uptake or Push/Back*). For example if a teacher asks, “What is the answer to number 3?” and then calls on three students for their answers without providing any information or questioning this would be coded as *Collecting*. *Connections* are when the teacher asks students to make an explicit link between two things, including comparing or contrasting. For example, “So how is Mary’s way of solving different than Joe’s way?” would be a question that is coded as *Connection*.

The specificity outlined between these moves testifies to the finer grain the ATM provides. If questions were merely being documented, these teacher moves would seem like open-ended or closed-ended questions; however, the ATM not only provides a more comprehensive examination of the classroom discourse by differentiating between questions that initiate the conversation (Initiating) and those in which the teachers is utilizing students’ responses (Rejoinder), but also specifies the ways in which teachers utilize those responses.

Table 5.2
 Categorization of Teacher Discourse Moves

Initiating Moves	Rejoiner Move
Launch	Terminal
Literal,	Lot
Re-initiate	Repeats
Redirect	Uptake
Think aloud	Uptake-Literal
Provides information	Push-Back
	Collecting
	Connection
	Not codeable

Infographics

After all transcripts were coded (codes were denoted on the corresponding transcript line), each teaching segment (whole group or small group discussion) was transformed into an infographic (Correnti, 2015). The infographic is a visual timeline of the classroom discussion with each teacher move displayed in sequential order within each teacher turn. Figure 5.1 provides an example of an infographic. The teacher turns, which are each time a teacher participates in the discussion, are represented within the columns and displayed in chronological order from the first turn to the last. All the moves within a turn are represented by the different colored boxes within each column and they are marked with the sequence order (e.g., 1, 2) For example, within teacher turn #8, the teacher initiated the turn by repeating what a student previously said, then she provided information, and ended the turn by asking a literal question. This data display was advantageous for analyzing patterns in teacher moves within a teacher's set of lessons and across teachers' lessons. Also, the organized display of move sequences of moves made it easier to score each discussion as described in the next section.

Each move a teacher makes within a discussion was given a score as shown in the scoring guide presented in Table 5.3. The preceding and subsequent moves, within and across turns, are examined when allocating points. The following transcripts provide an example of how the positioning of moves creates different opportunities for student learning. The same moves are used within each segment of classroom discussion, however the sequence in which they occur impacts the discussion and therefore points are allocated differently. Scherrer (2013) provides a rationale for the score for each move; the following section provides an overview of the scoring used within this study.

Table 5.3*Scoring Guidelines: Weighted Discussion Score Part 1*

Code	3	2	1	0	-1	-2
Launch	never	<i>default</i>	When it followed by any other code in the same turn	When the preceding code is also a <i>Launch</i> , regardless of whether it is in the same turn or not	never	never
Re-initiate	never	never	never	<i>default</i>	never	never
Literal or Uptake-Literal	never	never	never	<i>default</i>	When the preceding two codes are also <i>Literal</i> or <i>Uptake-Literal</i> , regardless of whether they are in the same turn or not When it is buried in a turn of four or more moves, regardless of its position	When the preceding three or more codes are also <i>Literal</i> or <i>Uptake-Literal</i> , regardless of whether they are in the same turn or not.
Uptake or Pushback	never	<i>default</i>	When the subsequent move in the same turn is <i>Literal</i> or <i>Uptake-Literal</i> When it is buried in a turn of four or more moves, regardless of its position	never	never	never

Adapted from Scherrer (2013)

Table 5.3, continued

Scoring Guidelines: Weighted Discussion Score Part 2

Code	3	2	1	0	-1	-2
Collect	never	When it is the last (or only) code in a turn and the subsequent turn begins with a <i>Connect</i>	<i>default</i>	When the preceding code is also a <i>Collect</i> , regardless of whether it is in the same turn When it is buried in a turn of four or more moves, regardless of its' position	never	never
Connect	<i>default</i>	When it is followed by another one move in the same turn When the preceding code in the same turn is also a <i>Connect</i>	When it is followed by any other two moves in the same turn When it is buried in a turn of four or more moves, regardless of its position	never	never	never
Lot	never	never	never	<i>default</i>	never	never
Repeat	never	never	never	<i>default</i>	When the previous turn also included a <i>Repeat</i> , regardless of its position	When the previous two or more turns also included a <i>Repeat</i> , regardless of their position

Adapted from Scherrer (2013)

Table 5.3, continued

Scoring Guidelines: Weighted Discussion Score Part 3

Code	3	2	1	0	-1	-2
Provides Information	never	never	never	<i>default</i>	When the preceding two codes are also <i>Provides Information</i> , regardless of whether they are in the same turn or not When the preceding two turns included <i>Provides Information</i> , regardless of its position	When the preceding three or more codes are also <i>Provides Information</i> , regardless of whether they are in the same turn or not
Think Aloud	never	<i>default</i>	When another <i>Think Aloud</i> appears anywhere in the previous two turns	When two instances of <i>Think Aloud</i> appear anywhere in the previous three turns	never	never
Terminal	never	never	never	<i>default</i>	never	never
NC	never	never	never	<i>default</i>	never	never

Adapted from Scherrer (2013)

Scoring Rationale. Within a mathematics discussion a teacher presents information, asks questions, and uses students' responses to address objectives of the lesson. As a teacher facilitates a discussion, certain moves position students to be the thinkers and doers of mathematics, while other moves position the teacher as the transmitter of knowledge (Scherrer & Stein, 2015). Teacher moves are assigned points according to the positionality of the students, with higher points allocated for moves that place the student at the center of the learning. There are three main categories of point distribution-positive score, negative scores, and neutral scores.

Positive Moves: Students as thinkers and doers of mathematics. *Launch*, *Uptake*, *Pushback*, and *Connection* moves are initially assigned positive scores because they position students to share their thinking, explain, and/or justify their claims. *Launch*, *Uptake*, and *Pushback* moves are assigned a default score of 2 points, while instances of *Connection* are given a default score of 3 points. *Connection* is awarded the most points because when students are making connections between their ideas and mathematical concepts, their learning is enhanced (Kazemi & Stipek, 2001). However, the affordances of these moves can be diluted when they are used in combination with other moves that do not allow students to respond. When a *Launch* is followed by another *Launch* before students have responded, it is only awarded 1 point instead of 2 points. Also, if an *Uptake* is followed by a *Literal* in the same teacher turn, the opportunities for students to provide explanations are overpowered by the immediacy to answer the literal question, and therefore the *Uptake* changes from 2 points to 1 point. The same is true for *Connection*; if it is followed by another move, it only receives 2 points, and if it followed by 2 or more moves, it is only assigned 1 point. Overall, if these

moves are followed by multiple questions within the same teacher turn, the power of the original move is diluted and therefore the score is lowered.

Instances of *Think Aloud* are assigned a score of 2 points. When students are able to hear their teacher model how to think through a problem and explain their choice of strategy, students are more likely to use the same process in their thinking (Webb, et al., 2006).

However, if a teacher over uses Think Aloud, the students are limited in their opportunities to share their thinking about a problem. The scoring takes this into consideration by reducing the number of points when there is a string of *Think Aloud* moves present in a discussion. For example, if two turns include *Think Aloud*, the first instance is awarded 2 points but the second is only awarded 1 point. If a third *Think Aloud* is present in a subsequent turn, then it is given 0 points.

Neutral Moves: Conversation Movers and Supporters. Within a discussion there are times when a teacher uses a variety of moves to provide more direct information to the students or gauge understanding. These moves, such as asking a literal question (*Literal* or *Uptake Literal*) are essential to support student learning because they allow for the teacher to clarify a concept or draw attention to a specific element of the mathematics. *Literal*, *Uptake Literal*, *Provides Information*, *Repeat*, and *Terminal* are all assigned 0 points when they occur independently within a teacher turn. However, when they used a sequence or in multiples, their point allocation becomes a negative value.

Negative Moves: Students as passive learners. Sometimes, teachers ask a series of literal questions or answer their own questions without allowing time for students to share and explain their thinking. These types of discussion moves position the students as more passive

participants and do not allow them to elaborate on their thinking. To account for these patterns of positioning students in more passive roles, moves are assigned negative scores when they occur in certain sequences.

A *Literal* is assigned a -1 point when it is directly preceded by 2 other *Literal* moves, and it is assigned -2 points if the preceding three moves are *Literal*. Also, as with other moves, if a *Literal* is a part of a turn with 4 or more moves, the move is often lost and therefore it is assigned -1 points. This coding scheme was also applied to *Uptake-Literal* moves. Similar to the way an abundance of *Literal* moves position the students to only give fact-based questions, an abundance of *Provides Information* positions students to passively engage with meaning making. If the preceding two codes are *Provides Information* or the preceding two turns include *Provides Information*, the current *Provides Information* is given a score of -1 points. *Provides Information* will be assigned a score of -2 points if it occurs after 3 or more codes of the same.

Repeat is a move that negatively impacts the classroom discourse community when used in abundance because it communicates a message that students do not need to attend to one another because the teacher will restate the information. When students' ideas are repeated to be made known to the class, the power is being taken from the students. It is important to make a distinction between repeating and revoicing. When a teacher revoices a student's response, usually the student has shared their thinking about an open-ended question and then the teacher rephrases the student's response to emphasize proper language or to clarify an idea (cite). Revoicing would not be coded as a repeat, but instead might take on the role of *Provides Information*, *Uptake*, or *Pushback*. To adjust for the lost sense of student

accountability a *Repeat* is assigned a score of -1 points when it followed a turn that also includes a *Repeat*, and it is reduced to -2 points when it is preceded by 2 or more turns that include *Repeat* moves.

Terminal moves are reduced in point value when they occur in subsequent turns as well. If a teacher is not using student responses turn after turn, student thinking is not being valued. Therefore, a *Terminal* is assigned -1 point if the previous turn also included a *Terminal* and a -2 if the preceded two turns involved *Terminal* moves.

Assignment of Weighted-Discussion Score (WDS) and Weighted-Positive Score (WPS). Each infographic was scored using the scoring system presented in Table 5.3. Each move was assigned a score and then the total score for the turn was also recorded. For each lesson, all the whole group discussion segments or small group discussions facilitated by the teacher were scored. For each lesson a WDS was calculated by adding the score for all turns within a discussion, and then an average was calculated for each teacher. The WDS reported herein will be an average of the teachers' discussions.

The Weighted-Positive Score (WPS) was calculated by adding the score for turns that resulted in positive points. These specific turns included *Launch*, *Uptake*, *Connection*, and *Think Aloud* moves and represented turns within the discussion in which the teacher was positioning the students to engage in more conceptual learning through explanation. The WPS reported herein will also be an average of teachers' scores. By recording this score, separate of the WDS, more information can be gleaned about the opportunities students had to engage in higher-level questioning. That is if a teacher has a WDS of -5, while it can be assumed that the number of negative scoring turns outweighed the positive or neutral turns, it is uncertain

the relationship between these types of turns. If the teachers' WPS score was 25, then there was a negative score of -30 to bring the total to -5 points, and therefore a high occurrence of negative scoring turns and positive scoring turns. On the other hand, a teacher may have a low occurrence of positive scoring moves, such as a WPS of 5 and still result in a WDS of -5. Knowing the WPS sheds light on the use of more open-ended moves that position students as active thinkers along with negatively scoring moves that position students into passive roles.

Discernment of Emerging Themes

After each WDS and WPS was calculated, the researcher was un-blinded to the teacher attributes and school contextual information that corresponded to each teacher within the subsample. A table was constructed to organize the WDS, WPS, and all quantitative data for each teacher. First, patterns between teachers' WDS and WPS were examined and infographics and transcripts were referenced to provide descriptive examples of the patterns. Next, patterns between MKT, WDS, and WPS were analyzed. Patterns that emerged were described using the infographics and transcript text. Finally, teachers' patterns within discussion, MKT, Nature score, and FRPL were referenced to help explain differences between teachers.

Chapter 6: Qualitative Findings

To better understand the discourse, specifically the level of student explanation and justification, within novice teachers' mathematics classrooms, the qualitative phase of this study was employed to examine the classroom discussions and the opportunities they afforded students. Transcripts of whole-group or small-group discussions facilitated by the teacher were coded, and each teacher move was categorized and scored using the ATM framework (Stein et al., 2015) and a weighted-scoring schema (Scherrer, 2013). After all discussions were coded, teachers were grouped based on MKT and patterns across discussions were examined. The current chapter will begin by presenting the patterns observed from a more global analysis of all participants within the subsample and then concentrating on groups of teachers based on MKT. Patterns will then be presented for the group of teachers scoring at least one standard deviation above the mean for this sample followed by patterns for the group of teachers with MKT scores at least one standard deviation below the mean. Research question 3 will be addressed within each section by describing patterns through WDS, WPS, infographics, and transcript excerpts. Research question 4 will be addressed through explicit attention to teachers' attributes and school SES in regards to patterns in discussions.

Patterns Across Sample

Table 6.1 presents each teacher's weighted-discussion score (WDS) and weighted-positive score (WPS) as well as school FRPL and MKT, Nature, and M-Scan discourse scores (Mathematical Discourse Community [MDC] and Explanation & Justification [EJ]) that were used in the quantitative analysis. The average WDS of the subsample ($M=-7.05$),

Dana: Holly, what do you think (perimeter) is?	Collecting
Student: It's four parts.	
Dana: You made it four parts. All right, so I've got this square. Okay, does the square have four equal sides?	Repeats, Literal
Students: (in unison) Yes.	
Dana: Yes. So I've got five here and five here. What do you think this is if they're going to equal?	Repeat, Provides Information, Literal
Students: (in unison) Five.	
Dana: Five because the square has what?	Repeat, Literal
Students: (in unison) Sides.	
Dana: Equal sides. So it's five and five. Okay, so to find the perimeter, I want to add five. So I'm going to $5+5+5+5$. Okay, what's $5+5+5+5$?	Repeat, Provides Information, Literal
Students: (in unison) 20.	
Dana: 20. Right. So do you know what perimeter has...where it is?	Repeat, Literal
Students: (in unison) 20.	
Dana: 20. Okay, that's what--perimeter is just when you add up all the sides. Okay, tomorrow, we'll start talking about area, and that gets a little more different.	Repeat, Provides Information
Student: I think I think areas.	
Dana: But perimeter you add up all the sides.	Provides Information

This excerpt shows that Dana starts by collecting a student's idea by asking "What do you think perimeter is?", and then, she begins a string of moves that repeat the students' responses and asks literal questions to walk through how to calculate the perimeter of a

square. This sequence of questioning solicits responses that ultimately are used by the teacher to explicitly present information instead of allowing students to share thinking; this is a common pattern within teachers' discussions in the subsample. An alternative to this progression would be to ask an open-ended question such as, "How would you calculate the perimeter of this square?"

The *Repeat* moves within the excerpt from Dana's lesson were restatements of answers to literal questions. Most of the *Repeat* moves used by the teachers in this sample would fall into this category; they commonly occurred after a *Literal* move and then were followed by another *Literal* move or a *Provides Information* move. It seems the teacher is fielding responses to involve students but pushing forward with a predetermined sequence of steps for approaching the mathematical content.

There were rare occurrences where the teacher engaged in the action of revoicing that extended a student's response or requested a student to contribute to clarification. These instances were depicted within the coding scheme as a *Repeat* move followed by *Provides Information, Uptake, or Pushback*. For example, in the following excerpt from Mona's second lesson, Mona engages in a series of interactions in which she repeats what the student has said and uses *Pushback* and *Uptake* moves to guide the student to clarify their thinking.

Mona: Why do you think 19 goes with the leftovers? Uptake

Student: Because they both can have 10.

Mona: Okay, they can both have 10. What would 10 plus 10 be? Repeat, Pushback

Student: I meant...I meant five.

Mona: Okay, but what's five plus five? Pushback

Student: Ten.

Mona: So 10. Our number is 19. So how could we pull it up to 19 and determine if it has leftovers or not? Where the twins would have the same amount or just over that? Repeat, PI, Uptake

Student: This would be a nine and a nine.

Mona: Okay. So he says that they each have nine. What would that be? Repeat, Uptake-literal

Mona used an *Uptake* move to continue the conversation about even and odd numbers. Then, she used *Repeat* moves to keep the student's response at the center of the discussion for the purpose of challenging the student to rethink his reasoning for 19 being even or odd. By repeating the student's response and then using a *Pushback* or *Uptake* move, she is extending the discussion with the student positioned as the sense maker. It is important to note that an open-ended question (*Launch* or *Uptake*) was necessary to set the stage for *Repeat* moves to be used in a way that extended a student's response. Due to the low percentage of *Launch* and *Uptake* moves, this pattern of revoicing was rare in this sample. *Repeats* were commonly used just as verbatim restatements of computational answers.

Although the *Repeat-Literal* pattern emerged as a common theme across the entire sample of mathematics discussions, additional patterns emerged when teachers were grouped based on MKT. The following section presents an overall comparison of teachers based on MKT. Subsequently, themes within each grouping (High MKT and Low MKT) will be further delineated and configurations of mathematics discussion will be linked to MKT, beliefs, and FRPL.

Table 6.1
Weighted Discussion Score (WDS), Weighted Positive Score (WPS), and other variables

Teacher	MKT Z-score	MDC	EJ	Weighted Discussion Score	Weighted Positive Score	Nature Raw Score	Nature Z-score	FRPL (%)
High MKT								
Lindsey	2.07	4.67	4	-17.33	17	11	-.63	43
Mikel	1.45	4.67	3.67	.33	13.67	15	1.23	71
Tyler	1.45	4.33	3.67	-12	8.67	15	1.23	45
Mona	1.45	3.6	3.67	14.75	36	10	-1.09	81
Jodi	1.03	4	3.67	-2.5	11.5	13	.30	12
Ashley	1.03	4.67	4	-8.5	10.5	10	-1.09	59
Mason	1.03	3.67	3	-21.33	7	14	.77	97
<i>Mean</i>		4.37	3.67	-6.51	15.10			
Low MKT								
Keri	-1.06	3	2.5	-19.75	11.25	10	-1.09	87
Ryan	-1.35	4.33	2.33	-1	9	16	1.69	95
Stacey	-1.36	3	2.33	-19.33	9.33	13	.30	74
Keira	-1.36	4.67	4.67	-.33	11	15	1.23	86
Becca	-1.53	3.67	3	0	11	11	-.63	57
Jennings	-1.53	2.67	1.67	7	12.67	13	.30	43
Dana	-2.07	2.67	3	-19.67	16	14	.77	78
<i>Mean</i>		3.43	2.79	-7.58	11.46			

Comparison between groups based on MKT

While teachers with higher MKT on average had higher EJ scores than their counterparts with low MKT, meaning that students were prompted to explain their reasoning more often and in more depth, the average WDS for these teachers was negative (M=-6.51) (shown in Table 6.1). The average negative WDS is a representation that average discussion orchestrated by teachers above one standard deviation included a majority of teacher moves

that positioned the students to be passive participants in the discussion. Echoing these results, the average WDS for teachers below one standard deviation was -7.58 (Table 6.1). Although the average WDS was negative, teachers with High MKT had a higher WPS (M=15.10) than teachers with MKT scores below one standard deviation (M=11.46). That is teachers with higher MKT used more teacher turns that included open-ended moves (Launch, Uptake, Connect) or models of strategies (Think Aloud) than teachers with lower MKT. The more frequent use of open-ended moves aligns with the higher EJ scores for this sample.

In addition to WDS and WPS scores for each teacher, the frequency of different types of moves were calculated and Table 6.2 presents the percentage of turns that included each type of move. As a note, some turns included more than one type of move; therefore, percentages do not add to 100 due to overlap. Table 6.2 shows that teachers with low MKT had a higher average percentage of moves that included *Literal* (41%) or *Uptake Literal* (18%) moves, while teachers with high MKT, on average, utilized a higher percentage of *Provides Information* (M=40%). Both teacher groups, High MKT and Low MKT, were similar in their use of *Repeat* with 37% and 36%, respectively. Lastly, teachers with higher MKT had a higher percentage of moves that included Launch, Uptake, Connection, Pushback, or Think Aloud moves (M=16%) than teachers with low MKT (M=13%). These moves were categorized as “Positive Moves” based on the fact that they were the moves that could result in a positive score for the turn in which they occurred. For example, when an *Uptake* moves was utilized its default score was a 2, while other moves may have a default score of 0 or a negative score.

Table 6.2 also presents each teacher's average number of turns per discussion, average length of whole-group discussion, and average turns per minute. Teachers with high MKT led whole-group discussions that were on average longer ($M = 16.65$) than the Low MKT group ($M = 14.16$). Also, during their discussions that were relatively longer, the High MKT group employed fewer teacher turns ($M = 49.85$) than the Low MKT group ($M = 70$). That is, teachers with high MKT led discussions that had longer periods of time between the occurrences that the teacher contributed to the discussion (teacher turn). This pattern is also reflected in that teachers with High MKT ($M=3.21$) engaged in one less turn per minute than teachers with Low MKT ($M=4.24$).

Although there are some differences noted by the averages between the different groups of teachers based on MKT, Table 6.1 and 6.2 show that there are diverse discussion patterns within each group. For example, within the High MKT group, Mona has the highest percentage of *Positive Moves* and highest overall WDS and WPS. However, Mason, also within the High MKT group, had the lowest overall WDS and lowest overall WPS. Although 15% of Mason's turns included *Positive Moves* (the overall average for *Positive Moves*), her discussion scores did not reflect this characteristic. Although she used moves that could have positioned the students to explain their thinking, they were used in a sequence that detracted from these opportunities by layering questions or not allowing students to respond before information was provided. This discrepancy between the frequency of positive moves and the WPS speaks to the limitations of merely a tallying of the types of questions asked by a teacher. The context in which the questions are asked bears weight on the opportunities provided to students. This unique characterization of teacher moves supports a closer

examination within the subgroups. The following sections present the results of a more concentrated examination within the subgroups. First, the High MKT group will be presented and then the Low MKT group.

Table 6.2
Percent of Moves per teacher turn, average turns and length of discussions

Teacher	Literal (%)*	Uptake Literal (%)*	Provides Info (%)*	Repeat (%)*	Positive moves (%)*	Av Turns	Av. Length (min)	Av. Turns/Minute
High MKT								
Lindsey	21	19	20	63	14	62	11.92	5.20
Mikel	15	15	22	18	13	50	19.67	2.54
Tyler	50	11	57	53	14	37	11.42	3.24
Mona	25	32	32	37	24	45	24.13	1.86
Jodi	40	11	42	23	12	58	13.5	4.29
Ashley	58	2	58	21	18	35	13.25	2.64
Mason	48	13	49	42	15	61	22.67	2.69
<i>Average</i>	37	15	40	37	16	49.85	16.65	3.21
Low MKT								
Keri	44	12	38	19	3	108	24.25	4.45
Ryan	40	16	30	47	20	31	8.67	3.58
Stacey	49	12	30	30	4	97	15.73	6.17
Keira	42	32	22	39	18	34	11.5	2.96
Becca	52	12	44	31	11	57	17.83	3.20
Jennings	44	21	23	38	21	32	8.83	3.62
Dana	42	19	34	49	7	70	12.33	5.68
<i>Average</i>	45	18	32	36	13	61.28	14.16	4.24
<i>Overall Average</i>	41	16	36	36	15	55.67	15.41	3.73

* % of turns that included the specified move

Teachers with MKT Above One Standard Deviation

Teachers within this subsample varied in their relative WDS and WPS, and the following sections will elaborate on three discussion types: Above Average WDS and Above Average WPS; Below Average WDS and Above Average WPS; and Below Average WDS and Below Average WPS.

Above Average WDS and Above Average WPS

Two teachers with High MKT were distinct in that they had positive WDS (2 of 3 in entire sample) and two of the highest WPS. Mona had the highest WDS (17.75) and the highest WPS (36) while Mikel has the third highest WPS at .33 and the fourth highest WPS (13.67).

Mona's discussions were characterized by numerous *Uptake* moves throughout the whole-group discussion. Figure 6.2 displays the infographics of her discussions. For example, the following excerpt from Lesson 4 shows Mona asking for further explanation instead of accepting the correct answer. In this lesson students identified even and odd numbers and justified their reasoning.

Mona: So she says 8 is even. Why is 8 even?

Repeat, Uptake

Student: Because you can split up into groups.

Mona: You can spilt it up into two groups she said. Let's try it.
How many would go on each side?

Repeat, Uptake-Literal

Student: 4

Mona: How did you do that?

Uptake

This type of interaction was common within Mona's discussions; however, as shown by the abundance of *Uptake Literal* moves (32% of turns), Mona often followed an *Uptake* move with a series of *Uptake Literal* moves that used students' responses to break down a process or rationale. In this sense the students' ideas were still being acknowledged, but opportunities to fully explain their ideas were limited to answering the series of literal questions that followed. This is reflected in the discrepancy between Mona's WPS of 36 and her WDS of 17.75.

Mikel did not press for explanations the way that was typical for Mona, as shown in Figure 6.3. However, in Mikel's discussions there were extended sections in which students were responsible for extending or challenging a student's solution method. In lesson 1 (turns 30-36) Mikel asks the class "Does anyone have anything else to add to what was already said about this problem?" and in lesson 2 (turns 42-51) she states "Let's see if we agree or disagree with Jessie." In these two sections students led the conversations; the sections of the infographics look distinct with the clustering of green *Uptake Moves* and missing *Literal and Provides Information* moves. These sections drive the WPS for Mikel, and although they are relatively short, her surrounding moves are not overpopulated with long strings of *Literal* questions or *Repeat* moves that would detract from her overall score. On the other hand, Mikel does have short sections of consecutive *Provide Information*, in which students are walking her through a multi-digit subtraction problem, and short sections of consecutive *Repeat* moves that occurred when she was fielding students' responses to a Venn diagram to compare addition and subtraction. These segments help explain the discrepancy in her WPS (13.67) and her WDS (.33).

Both Mona and Mikel taught at schools with a high percentage of students receiving FRPL (81% and 71%), but they differed in their *Nature* scores with Mona below one standard deviation of the sample's mean (-1.09) and Mikel above one standard deviation of the sample's mean (1.23). The evidence of higher WPS in contexts with higher FRPL supports the quantitative findings that FRPL was not a predictor of the level of EJ. That is, the qualitative coding did not find differences in open-ended questioning between low and high FRPL contexts. Lastly, the higher WPS of these discussions also does not provide support of the predictability of discourse based on teachers' epistemological beliefs (*Nature*). It is important to note that the small subsample limits the range of discussions analyzed, and this may limit the accessibility to patterns based on belief scores.

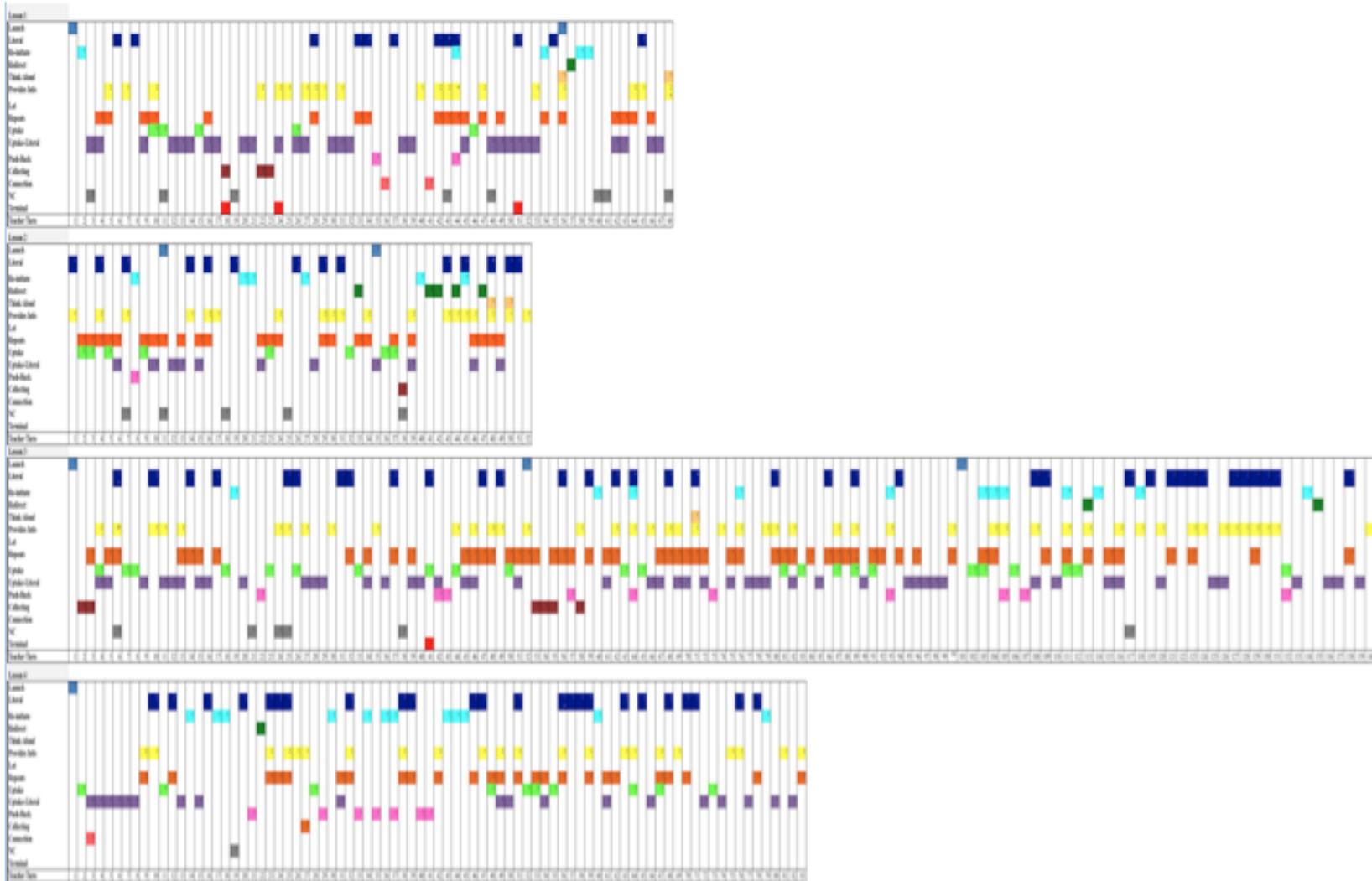


Figure 6.2 Pictures of Mona's discussions

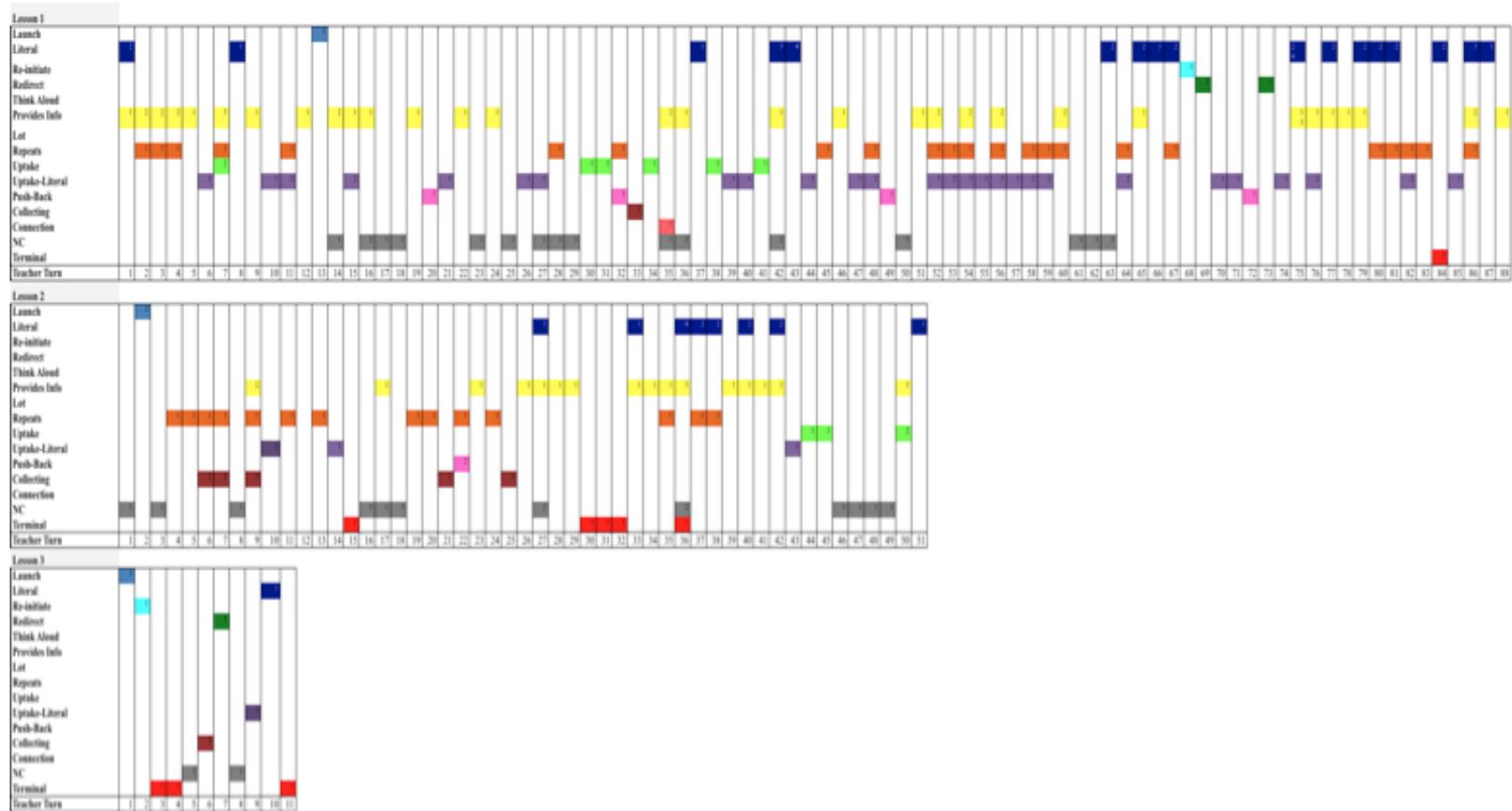


Figure 6.3 Pictures of Mikel's discussions

Below Average WDS and Above Average WPS

Only one teacher, Lindsey, within the High MKT group displayed a relatively higher WPS but a negative WDS. A defining characteristic was that Lindsey had the highest MKT of the larger sample of teachers (MKT Z-score = 2.07). To provide more context, Lindsey reported a relatively low *Nature* Score (Nature Z-score = -.63) and taught at a school with a FRPL lower than the sample's average (43%).

Lindsey has the second highest WPS (18.33); however, there was a 34-point discrepancy between her WPS and WDS (-16.33). As shown in Figure 6.4 Lindsey's discussions are made up of a majority of turns that include a *Repeat* move (63%), and this results in an extensive reduction of points due to the diminishing impact on students' accountability to one another. Also, each discussion includes series of consecutive *Collecting* moves, and these patterns reduce the positive points assigned to *Collection* moves to a neutral score of 0. This neutralization of points reflects the offsetting impact of not tending to the mathematics within the responses when soliciting student ideas. For example, in each of her lessons Lindsey asked a question such as "What are some things we have learned about measurement?", and then she proceeded to field student responses without making a connection between responses or elaborating on ideas. The students share their ideas, but their ideas are not utilized.

Lindsey's first lesson, while exhibiting characteristics of the other two lessons in terms of consecutive sequences of *Repeat* and *Collecting*, included more instances of *Launch* and *Uptake* moves. This discussion was centered around shape attributes, and Lindsey asked more open-ended questions to explore students' understanding of the shapes such as "How do you know this is a 2D shape?" or "Tell me what you know about a circle." Moves such as these increased her WPS to be one of the highest in the sample. The topic, shape attributes, seemed to lend itself to

more open-ended questions and opportunities for student to describe their thinking. However, the negative patterns of collecting and repeating students' responses overpowered Lindsey's efforts to position students to develop and share their own ideas. This unbalance is striking in that a discussion with a relatively higher WPS could result in a WDS that was more characteristic of discussions that did not include positive moves.

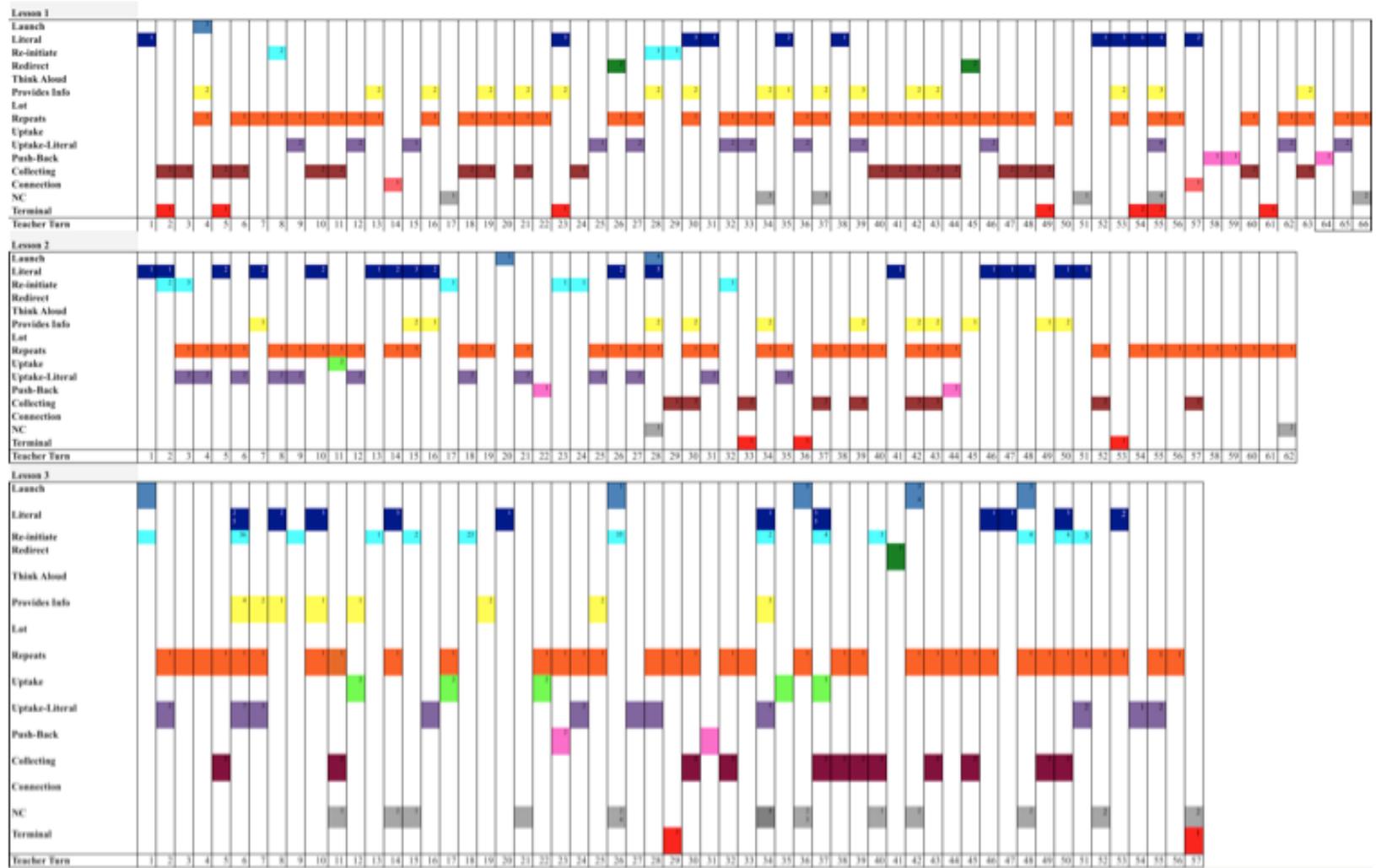


Figure 6.4 Pictures of Lindsey's Discussions

Below Average WDS and Below Average WPS

Mason and Tyler were two teachers with high MKT, the lowest WPS of the subsample, and low WDS. Mason had the lowest WDS and WPS of the entire subsample. Tyler had the second lowest WPS but was at the median in term of WDS. Both teachers reported more sophisticated views of mathematics ($M(Nature)=14.5$), and Mason taught at a school with high FRPL (97%) while Tyler taught at a school with a FRPL level (45%) that was below the national average of 49.6% (U.S. Department of Education, 2013).

One commonality between the discussions orchestrated by Mason and Tyler is the frequency of *Provides Information* moves and the extended length of these moves within a turn. As illustrated in the infographics in Figure 6.5 and Figure 6.6, 57% of Tyler's turns and 49% of Mason's turns included *Provide Information* moves. Transcripts of each teacher's discussions were engulfed by lengthy teacher explanations to questions asked to the students.

The following excerpt provides an example:

Tyler: What is my whole going to look like? Carlos.	Literal
Student: It's going to look like eight eighths	
Tyler: Yeah, it's going to look like eight eights. Why? If I've got a fraction bar and I split it into eights and split into halves, and split the half into halves, and split those, which are fourths, into halves. Now, I've got eight. When I make one whole here, one whole candy bar and I cut it up whole and I color in eight pieces out of the eight that it was split into. That's eight eighths is actually one whole. I believe some of you can see that. Awesome. So we've got eight eighths as our total here, and we're going to have them split the whole candy bar...So what is one way that we could split the candy bar so that two people have parts in it?	Repeat, Uptake Provides Information Provides Information Literal

Tyler provides a lengthy explanation of the equivalency of eight-eighths and a whole, and in response to the subsequent questions, she fields a student's response but then interjects to further explain an alternative way to split the candy bar. Mason engages in similar discussion moves.

In addition to a preponderance of *Provides Information* moves, Table 6.2 shows that a majority of Tyler and Mason's turns include *Repeat* (53%, 42%) and *Literal* moves (50%, 48%). This is common practice across teachers with high and low MKT that results in a lowering of the WDS. Figure 6.4 and Figure 6.5 illustrate the common *Repeat-Provides Information-Literal* pattern in Tyler and Mason's discussions. Also, the relative absence of *Launch* and *Uptake* moves, reflected in low WPS scores, characterizes the discussions as limited in opportunities for students to explain their thinking.

Mason and Tyler, provide non-examples of the quantitative findings in that their high levels of both MKT and reported epistemological beliefs do not seem to predict a high level of EJ within mathematics discussions, as indicated by their WDS and WPS. This highlights the differences in discourse measures used in the quantitative (M-Scan) and qualitative (ATM) phases.

Summary

Upon close examination of the discussion patterns of teachers with High MKT, evidence emerged in support of MKT as a significant predictor of the level of EJ within the lessons. Teachers with high MKT used open-ended moves within their lessons and engaged in fewer teacher moves per minute. That is, teachers with higher MKT positioned students to

contribute more during their classroom discussions, and this bears influence on the overall indicator of opportunities for explanation and justification. The balance between these types of moves varied within the subsample, and this is where distinct differences were noted. Although FRPL and Nature scores were referenced throughout the analysis, no patterns emerged to provide further clarity in regards to the influence of these factors on classroom discourse.

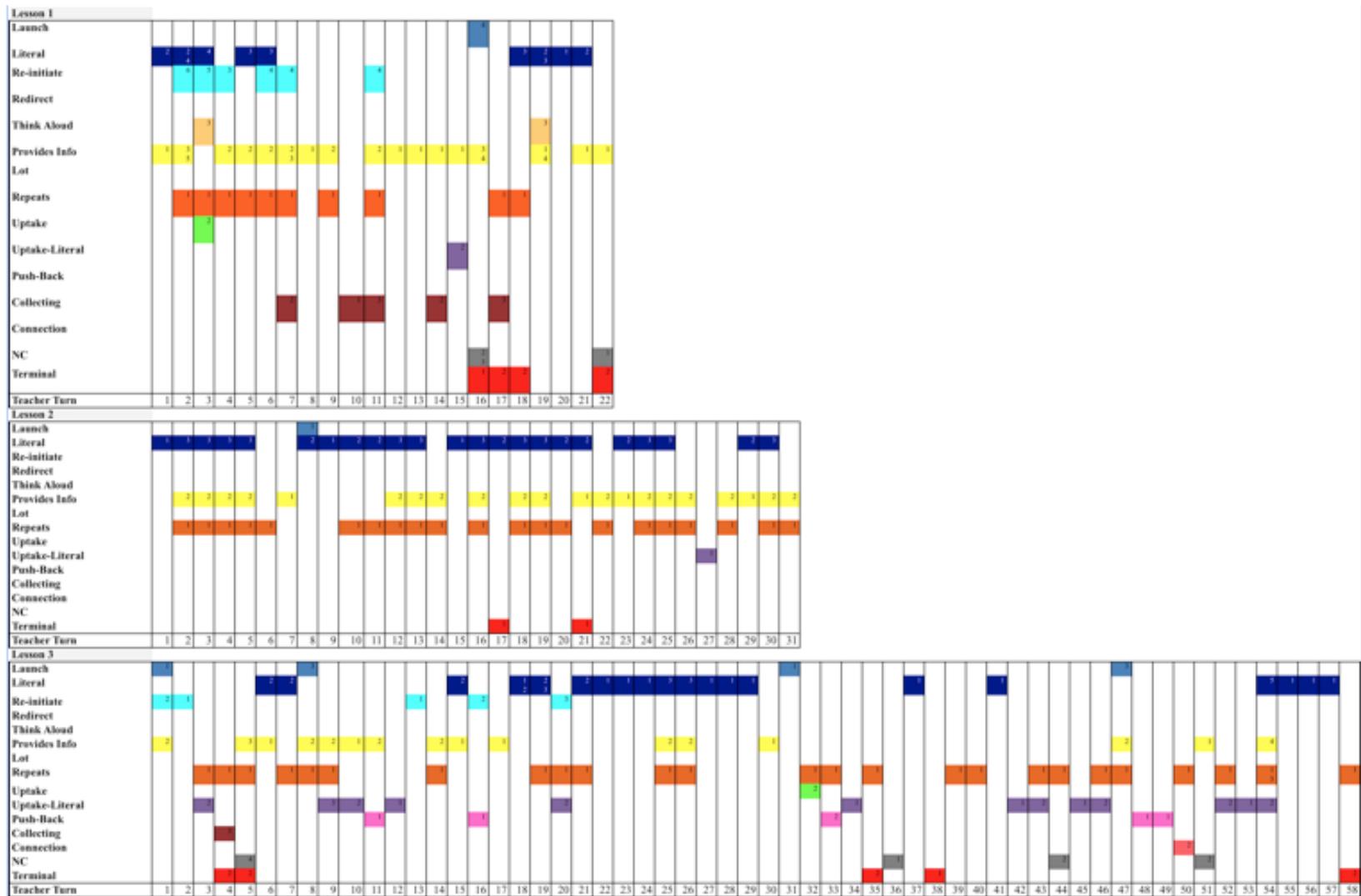


Figure 6.5 Pictures of Tyler's Discussions

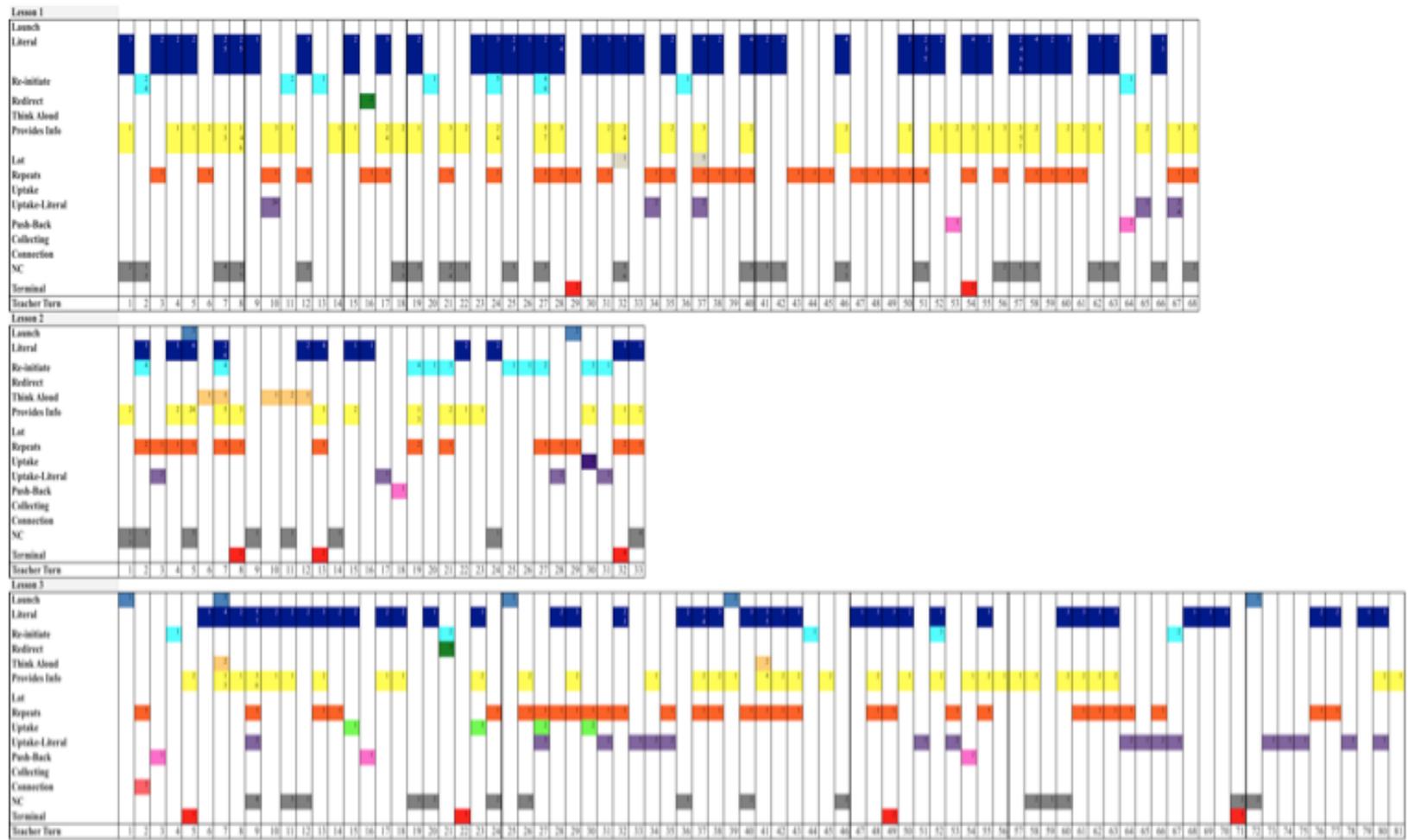


Figure 6.6 Pictures of Mason's discussions

Teachers with MKT Below One Standard Deviation of Sample

Similar to the subgroup with High MKT, teachers within this subsample of Low MKT varied in their relationship between WDS and WPS. However, only one teacher in this Low MKT subgroup had a WPS that was above the average for the complete sample. As a result, different groupings were examined to better understand the patterns within the discussions. First, patterns within teachers with above average WDS are presented. Next, one teacher's discussions are described that had an above average WPS. Lastly, discussions from two teachers below average WDS and below average WPS are reported.

Above Average WDS

Jennings and Becca were the only two teachers with Low MKT that did not have negative WDS (Jennings = 7; Becca = 0). However, their WPS were below average ($M = 13.27$; Jennings = 12.67; Becca = 11). Jennings and Becca were different in regards to Nature scores, in that Jennings had slightly higher Nature scores than the sample's average, and Becca had a slightly lower score. They both taught at schools with FRPL percentages (43% and 57% respectively) that were less than the sample's average but aligned with the national average at 49.6%.

Jennings, a Kindergarten teacher, led discussions about the composing and decomposing numbers. A majority of her positive moves were Pushback moves in which she challenged a student's representation of a number. The following excerpt serves as an example:

Jennings: David, how did you represent the number 6? How many in one box and how many in the other? Literal, Literal

Student: 2 and 5

Jennings: I want you to double check. Pushback
Student: Yes, that's right.

Jennings: You were supposed to represent the number 6. Think on it. Pushback

She pushes the student to make sense of the number by pushing back on their response. Jennings does not ask many open-ended questions (Launch, Uptake) but instead uses Pushback moves after students respond to Literal questions about the parts of a number. The Pushback moves are the basis of Jennings WPS (12.75); her final WDS is positive (7) due to the fact that she does not engage in consecutive *Repeat-Literal* moves, but instead spaces out literal questioning which is depicted in Figure 6.7 of her discussions. Also, Jennings engaged in shorter discussions that consisted of turns of less than 3 moves. Her turns were more simplistic; therefore, her WPS was not subjected to a reduction in points due to multiple moves or distracting patterns. In each lesson, Jennings's whole group work was followed by independent or pair work on the day's mathematical number topic (e.g., decomposing within 5).

Becca also engaged in discussions that resulted in a WDS that was above average. Becca utilized a larger proportion of *Literal* questions within her discussions (53%), however, the questions were often chunked within turns that involved her providing information or responding to a student's idea with another question (*Uptake-Literal*, *Uptake*) (Figure 6.8). Also, Becca did not use *Repeat* moves as frequently as her peers, and therefore

her WDS was not as influenced by the negative score that subsequent *Repeats* are assigned. She spaced out her use of Repeat moves and therefore she was not engaging in a pattern of moves that implicitly communicated to students that they did not need to listen to one another. Lesson #2 had more sections of discussion with consecutive series of literal questions; however, this lesson also had a section in which *Uptake* moves were used to investigate patterns between numbers on a hundreds board. Within this portion of the lesson, Becca asked the students to explain why they chose certain numbers to fit the pattern and how they knew it worked.

Overall, Jennings and Becca's use of positive moves within their discussions, although relatively few, were not negated by long strings of *Literal*, *Provides Information* or *Repeat* moves. While *Literal* moves were still used frequently, the positioning of these moves still allowed for student responses to be shared and *Pushback* moves were more commonly used. The fewer open-ended moves are reflected in lower EJ scores for both teachers (Jennings = 1.67; Becca = 3). However the findings seem to indicate that although they are not orchestrating student-centered discourse, at the same time they are engaging in patterns that negatively position the students through unproductive sequences of literal questioning or constant repetition of students' responses. Oversimplified, it seems these teacher seemed to neutralize their classroom discussion by engaging in a balance of student-centered and teacher-centered moves.

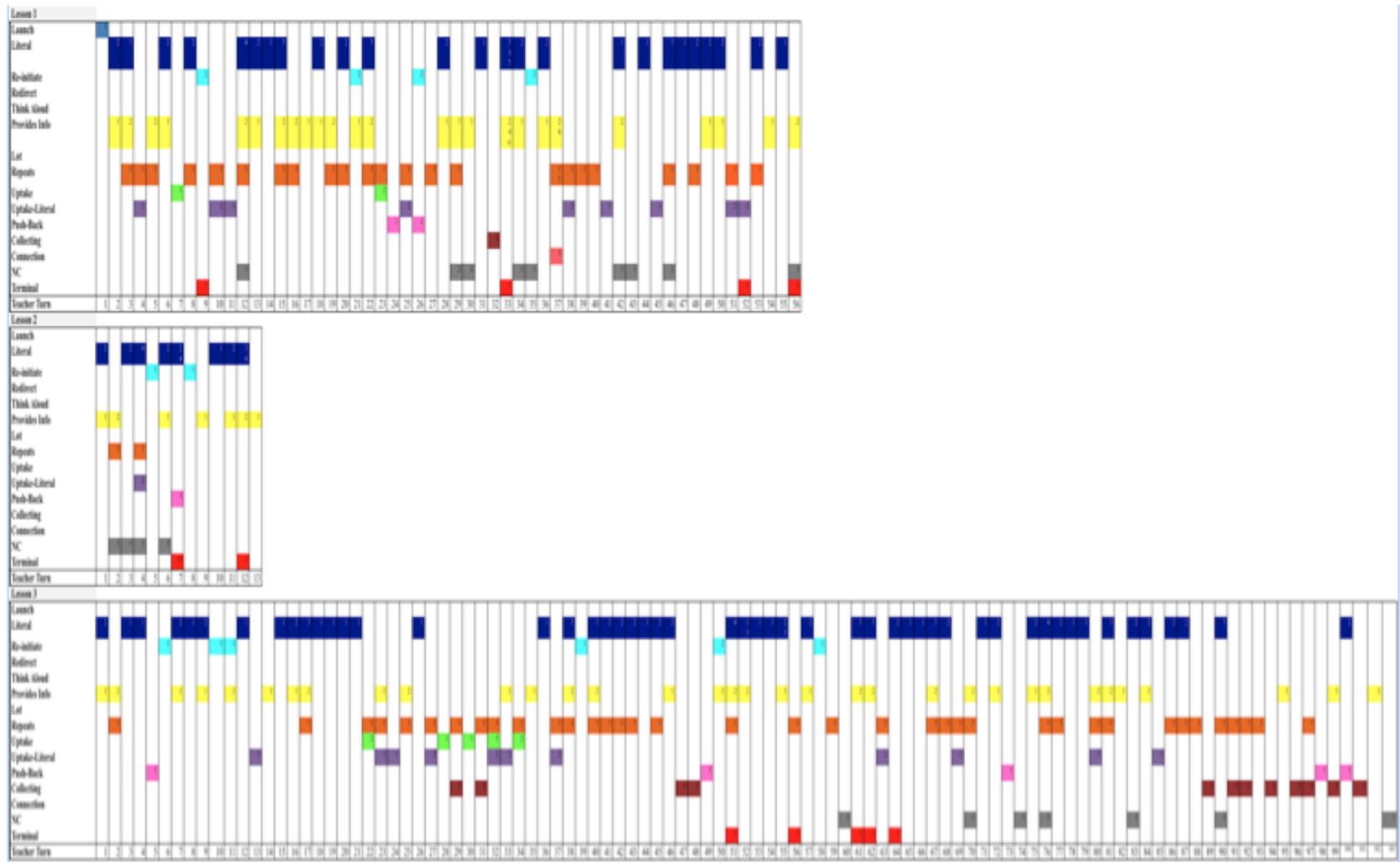


Figure 6.8 Pictures of Becca's discussions

Below Average WDS and Above Average WPS

Dana was the only teacher in the Low MKT subgroup that had a WPS that was above average. However, 35.67 points in negative moves counteracted her WPS of 16, resulting in a WDS of -19.67. Ironically while Dana reported the lowest MKT of the overall sample, Lindsey, the participant categorized as below average WDS and above average for the High MKT subgroup, reported the highest MKT of the overall study. Similar to Lindsey, Dana's discussions involved, on average, more teacher turns (70) than most of the teachers in the sample. Unlike Lindsey, Dana had a higher *Nature* score than the sample's average and taught at a school with a higher FRPL (78%) than the sample's average.

While all three of Dana's lessons, as shown in Figure 6.9, included stretches of consecutive *Repeat* and *Literal* moves, the first two lessons include lengthier stretches of these moves. These consecutive patterns result in negative scores for numerous of her turns. The third lesson differs in that Dana did not repeat students as often and also utilized more *Uptake-Literal* and *Pushback* moves. Similar to Jennings, most of Dana's moves that extended students' involvement with an idea were *Pushback* moves. These moves challenged students' thinking; however, her lack of *Uptake* moves narrowed the opportunities for students to engage in more open-ended questioning.

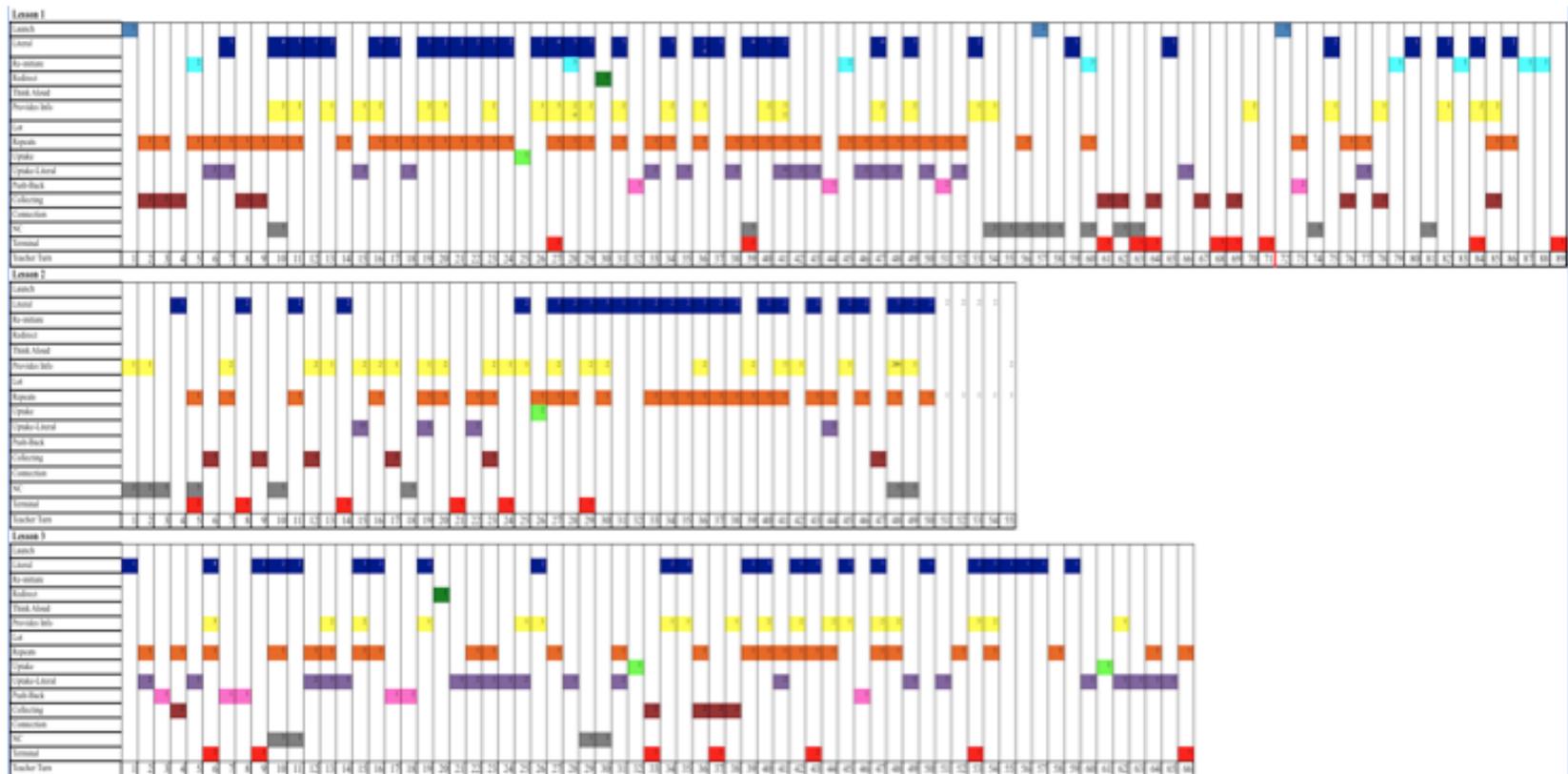


Figure 6.9 Pictures of Dana's discussions

Below Average WDS and Below Average WPS

Keri and Stacey employed whole-group discussions that included relatively few positive moves (WPS); although they used the most teacher moves (108, 97) on average. More specifically, only 3% of turns in Keri's discussions and 4% of turns in Stacey's discussions included positive scoring moves. Also, both teachers had high teacher turns per minute with Keri engaging in an average of 4.45 turns per minute and Stacey the highest at 6.17 turns per minute. Both teachers taught at schools with higher FRPL populations (87% and 74%) than the average of the sample and the national average. Keri had a lower Nature score than the sample's average (Nature Z-Score = -1.09) while Stacey had a Nature score that was slightly higher than the average (Nature Z-Score = .30).

Keri and Stacey conducted discussions that had a high proportion of *Literal* and *Provides Information* moves, parallel to the patterns across the overall sample. As shown in Figure 6.10, both teachers engaged in successive turns with *Literal*, *Repeat*, and *Provides Information* without *Uptake*, *Connection* or *Pushback* moves that would have extended or utilized students' responses. The lack of open-ended questions were reflected in the short student responses, usually a short phrase or sentence that filled the lesson transcripts.

A distinct pattern within Keri and Stacey's discussions was the considerable number of *Terminal* and *Not Codeable* moves that are illustrated by the grey and red sections of the infographics. *Terminal* moves are teachers' responses that end a student's contribution to the discussion by evaluating their responses and moving on to a new question or topic. When following a *Literal* or other questioning move, a *Terminal* is the final portion of a series that is categorized as a traditional Initiate-Respond-Feedback (Mehan, 1979) sequence. Keri and

Stacey's *Terminal* moves involved blunt responses of "No" to students' answers or "Good job" before they asked a new literal question or collected another student's response. Also, both teachers had numerous turns that included utterances in reference to classroom management. That is, both teachers had to interrupt talk focused on mathematics to redirect student behavior or attend to logistical issues of the classroom. These moves were coded as *Not Codeable* and often made it difficult to follow the flow of the conversation.

Summary

The lack of open-ended questions (*Uptake and Launch* move) within the discussions of teachers with Low MKT supports the quantitative findings of lower EJ scores for this group of teachers. The teacher-centered nature of the discussions is perhaps accentuated by the number of moves a teacher takes during a turn and the number of turns that are squeezed into the discussions. This paints the picture of a teacher busy at work while students provide short, quick responses. Similar to the High MKT analysis, little evidence emerged in regard to the influence of teachers' beliefs (*Nature*). There is evidence of teachers with varying contexts engaged in similar patterns and teachers with similar contexts engaged in contrasting patterns. This points to the need for a larger sample size to better investigate these factors.

Overview/Summary

Upon closer examination of the discussions within grouping based on MKT, similarities across groups emerged. The abundance of *Repeat*, *Literal*, and *Provides Information* combinations, even within single turns, occurred across all lessons. Discussions in the High MKT group varied more than the discussions in the Low MKT group; however,

the distinguishing feature was the higher proportion of *Launch* and/or *Uptake* moves that were present for teachers with high MKT that were not present for teachers with low MKT. Overall, the qualitative analysis of classroom discussions supported the quantitative findings in regard to the relationship of MKT and EJ, but did not produce evidence of the relationship of teachers' epistemological beliefs (*Nature*).

Chapter 7: Discussion

The mathematics discourse within the classroom unveils the mathematics content (Michaels & O’Conner, 2003) as well as the social positioning of students (Scherrer, 2013). This study examined the mathematics discourse within novice elementary teachers’ classrooms to better understand the teacher attributes and school contextual factors that promoted and hindered student-centered mathematics discourse. The first phase of the study, the quantitative phase, conceptualized two levels of student-centered discourse. First, a more holistic measure of the mathematical discourse community was utilized by evaluating the frequency of: solicitation of students’ ideas; opportunities for students to talk to one another about the mathematics; and open-ended questions (MDC score). Next, students’ mathematical explanations and justifications were examined and rated based on frequency and depth (EJ score). The second phase of the study analyzed specific teacher moves during discussions and how those moves positioned students. This study’s multifaceted approach for examining novice teachers’ facilitation of mathematical discourse offers significant implications for the field of mathematics education and more broadly for the field of teacher education. The following sections address findings, implications, and limitations. First, the key findings are presented. Next, findings are situated within current research and implications for teacher educators and researchers are discussed by focusing on the foundational components of the study: (a) novice mathematics teachers’ discourse, (b) school contextual factors, and (c) teacher attributes. Subsequently, limitations of the study are addressed and finally, future research for teacher education is delineated

Key Findings

To provide a summary of key findings, the research questions will be stated with a concise statement of results.

Research Question 1: What teacher attributes and school contextual factors account for variation in the level of mathematical discourse community between novice elementary teachers' mathematics lessons?

The only teacher attribute that accounted for variance in the level of MDC was teachers' epistemological beliefs about the nature of mathematics (*Nature*). School context was related to MDC in that FPRL had a negative relationship with the level of MDC and TPSS was a significant predictor of MDC.

Research Question 2: What teacher attributes and school contextual factors account for variation in the level of students' explanation and justification between novice elementary teachers' mathematics lessons?

When analyzing EJ, only MKT and *Nature* were significant predictors of the level of EJ in lessons. Teacher with higher MKT scores and more availing or sophisticated beliefs about the nature of mathematics had higher EJ scores on average.

Research Question 3: How do novice teachers of varying attributes and in different school contexts utilize specific teacher moves to orchestrate classroom mathematical discussions?

Based on the coding of teacher moves using the ATM framework, all teachers regardless of their attributes or school context frequently used *Literal*, *Repeat*, and *Provides Information* moves. A common pattern across teachers was to use *Literal*, *Repeat*, and *Provides Information* moves in succession to create sequences in which the teacher would

solicit participation through literal questions while providing the necessary content. Teachers with High MKT utilized more *Launch*, *Uptake*, and *Pushback* moves. If teacher with Low MKT did engage in positive moves it was commonly *Pushback*. No patterns were detected between teachers with varying Nature scores. Lastly, due to the binding of the coding to only classroom discussions, FRPL was not examined in relation to teacher moves due to its statistically significant relationship with MDC that is measured based on whole-lesson discourse opportunities.

Research Question 4: In what ways do the patterns of teacher moves within mathematics discussions help to explain the quantitative results about teacher attributes and school context?

The more frequent use of student-centered moves (*Launch*, *Uptake*, *Pushback*, *Connection*) by teachers with High MKT justified their higher EJ scores. By engaging in these moves, teachers with High MKT positioned students as the ones responsible for the thinking, resulting in an outcome of increased explanation (EJ). Furthermore, teachers with High MKT engaged in fewer teacher turns within their discussions and therefore it can be presumed that students were sharing their thinking more. This evidence supports higher EJ scores due to the more frequent opportunities for students to share their ideas.

Implications of Findings

The following section will situate the study's findings within the current literature and delineate implications for teacher educators and researchers. The section will be organized based on the key concepts of the study (a) novice mathematics teachers' discourse, (b) school contextual factors, and (c) teacher attributes.

Novice Mathematics Teachers' Discourse

Upon analysis of a subsample of teachers' discussions, the predominance of literal questioning and direct transmission of information illuminates the teacher-centered nature of many of the classroom discussions. Although only the teacher-facilitated discussions were analyzed, past research suggests that the patterns noted within the teacher-facilitated discussions are in fact indicative of other student-to-student discussions within a classroom (Kazem & Stipek, 2001; Webb, Nemer, and Ing, 2006). Therefore, it is plausible that the coded discussions for a teacher are representative of all classroom interactions as a whole within that teachers' classroom.

Although there was variation in MDC and EJ scores, the high proportion of literal questions perhaps speaks to the novice teachers' desire to avoid student responses in which they were not prepared to interact. Livingston and Borko (1989), in their study of novice and experienced teachers, found that novice teachers became flustered when they were faced with a question or student response in which they had not anticipated. In this sample of novice teachers, perhaps the abundance of literal questions were used to solicit student participation through simple, factual answers instead of opening up the discussion through more open-ended questions. As teacher educators design experiences for teachers to engage with discourse strategies, this finding supports efforts to build teachers' confidence in facilitating open-ended questions. By providing structured practice with talk moves (Chapin, O'Connor, & Anderson, 2013), teacher educators can build teachers' repertoires and provide feedback on their use of these strategies. Explicit instruction about these discourse moves could increase self-awareness of the frequent use of *Literal* moves and scaffold the use of *Uptake*

moves. Through systematic self-analysis teachers can see the benefits of moves such as “Tell me more” or “What do you think about that?” (Chapin, O’Connor, & Anderson, 2013). These moves also allow for instructional coaches and/or mentors to continue with common language and strategies during the induction years to further support teachers growth in their use of more open-ended discourse moves.

In addition to the high percentage of literal questions and direct telling of information, a substantial proportion of teacher turns began with them echoing a student’s previous response. After repeating a student’s response, teachers commonly asked a follow-up question (Uptake-Literal), provided information (PI), or asked a new question (Literal). For this sample the evaluative portion of the traditional IRE sequence (Cohen, 1989) seems to be replaced by a *Repeat* move in which the teacher echoes the student’s response instead of providing an evaluation of it. This type of discourse move has the potential to emphasize a student’s contribution or extend an idea through elements of revoicing (O’Connor & Michaels, 1993, 1996; Chapin, O’Connor, & Anderson, 2013). However, the patterns noted within this sample did not develop past what seemed to be the habit of verbatim repetition of factual responses. For those instances where the teacher did engage in revoicing, the positioning of the student’s idea was not represented in the coding used. For example, if a teacher revoiced a student’s idea by restating and augmenting with more precise language or clarification of a concept, these utterances might be coded as *Repeat, Provides Information*. This coding sequence does not capture the role revoicing plays in positioning students as the creators of the knowledge (Chapin, O’Connor, & Anderson, 2013), and this warrants modifications for future use of the ATM coding scheme.

The qualitative coding process using the ATM coding scheme (Scherrer, 2013) revealed that talk moves such as turn-and-talk and student restating one another (Chapin, O'Connor, & Anderson, 2013) would enhance this analysis tool. Turn-and-talk directions by the teacher were coded as *Not Codeable* within this current study, but upon further analysis of transcript excerpts the positive influence of these segments seemed to be missed opportunities for the characterization of teachers' discourse practices. Also, when a teacher asked a student to restate another student's idea this move was coded as a *Connection*, but this code does not reflect that the action of verbalizing. The overall coding guide would benefit from a specification of these moves (revoicing, turn-and-talk, and restating) to support the explicit use of these moves that are outlined in research and teacher education resources (Chapin, et al., 2013).

In addition the ATM coding scheme could serve as a powerful learning and feedback tool for teacher educators to use with pre-service and in-service teachers. Often novice teachers are more focused on their actions as independent of their students instead of analyzing how their actions promote or hinder student learning (Livingston & Bork, 1989; King & Kitchner, 1999). The ATM guide can provide specific evidence of how the teachers' moves position the students and the patterns in which they engage (Scherrer & Stein, 2013). The infographic or coded transcript of a classroom discussion can serve as feedback and a learning tool to show appropriate places to insert different types of moves (*Uptake* or *Connection*) that will position the students as mathematicians.

Orchestrating student-centered discourse is difficult for teachers (Cohen, 1988; Herbel-Eisenmann, Lubienski, & Id-Deen, 2006; Stigler & Hiebert, 1999), but by analyzing

the variability in a relatively homogenous novice teacher population (based on college level entry characteristics), this study was able to identify variables that afforded or hindered this orchestration early in a teacher's career. The following sections discuss the impact and implications of school context, teacher beliefs, and MKT on the level of student-centered discourse within the teachers' lessons.

School Context

The main variables that were analyzed in terms of school context were school SES (FRPL), teachers' perceptions of support of mathematics (TPSS), and grade level. The quantitative results reported that FRPL and TPSS were significant predictors of teachers' level of MDC but not EJ, and grade level was not a predictor of either level of discourse.

Teachers who taught at schools with a higher percentage of students eligible for FRPL engaged in mathematics lessons that had less student-centered mathematical discourse communities (MDC). In order to decipher what that means, the MDC construct must be revisited. The MDC construct is comprised of indicators that measure: solicitation of students' ideas, student-to-student discourse, and the opportunity for open-ended questions. Lower MDC scores could be a result of few opportunities in all these areas, or one more so than another.

Although the qualitative analysis revealed that all teachers in the subsample frequently solicited students' contributions, mostly through literal questions, the qualitative analysis, limited to 14 participants, was bound to segments of classroom discussion and therefore the entire lesson was not captured. In contrast, the MDC construct was measured for the entire lesson, and therefore the experiences in classrooms of varying FRPL

percentages were different in terms of students' opportunities for discourse across the entire lesson. Despite this important finding, further study is needed to fully understand the relationship between FRPL level and MDC. It seems that the MDC score is being driven by a lack of opportunity for student-to-student discourse and/or lack of open-ended questioning.

Furthermore it was hypothesized that FRPL would predict the level of EJ, but this was not supported due to the lack of variation in teachers' EJ scores based on FRPL within the quantitative analyses. Additional studies are needed to better understand the differences between teachers in this area. The qualitative results were inconclusive in regard to differences in opportunities for open-ended questioning between teachers with contrasting FRPL. Three teachers with the lowest percentage of positive moves (Keri, Stacey, and Dana) taught at schools with above average FRPL; however two teachers with the highest percentage of positive moves (Mona and Ryan) also taught at schools with the highest FRPL.

This study reported differences in the overall MDC based on FRPL, but did not detect differences in students' levels of explanation and justification. Past research about instructional practices within classrooms of differing SES also have reported mixed results with some research concluding that students of lower SES receive predominantly procedural instruction (Diamond, 2007; Desimone & Long, 2010; Lubienski, 2001) while others report no such discrepancies (Minor, Desimone, Phillips, & Spencer, 2015). While these studies analyzed the associations between mathematics instruction and SES using broader categories such as procedural or conceptual instruction, there has been little attention to the interactions within the classroom.

More attention is needed in terms of the student interactions and other instructional strategies to better understand the well-documented disparities between socioeconomic status (SES) and students' mathematics achievement (Ma & Klinger, 2000; Ho, Caprora, Caprora, 2015, Zhang, 2009). The ATM coding scheme provides a rigorous method for analyzing the positionality of students, and this measure could be used to better understand the opportunities afforded to students from different SES backgrounds. Due to the small sample size in the current qualitative analysis, patterns were not detected. With a larger sample size and explicit sampling based on SES, more information could be gleaned from the classroom discussions.

Lastly, hypotheses about TPSS and grade level were supported by findings in that TPSS was only predictive of MDC and grade level did not predict either MDC or EJ. Teachers that reported more support in regard to mathematics taught lessons that involved higher levels of student solicitation, student-to-student talk, and/or more open-ended questions, but further investigation is needed to understand the extent to which each of these elements occurred. This finding aligns with past research that found teachers were more likely to implement student-centered strategies if they were supported by their team (Lewis, 2007), and points to the relation between discourse practices and school context. Also, grade level was not significant predictor of classroom discourse, supporting the hypothesis that other factors would be more influential.

Teacher Attributes

While FRPL and TPSS accounted for variance in the level of MDC within teachers' lessons, teachers' epistemological beliefs about the nature of mathematics (*Nature*) also predicted MDC. Furthermore, *Nature* and MKT were significant predictors of the level of EJ within teachers' lessons. To note, teacher's epistemological beliefs (*Nature*) predicted both MDC and EJ. Both of these teacher attributes will be discussed in the context of current research in the following subsections.

Epistemological beliefs. This study found that teachers' self-reported beliefs about the nature of mathematics predicted the level of MDC and EJ within their mathematics classrooms, which aligned with hypothesized outcomes. That is, if a teacher had more sophisticated beliefs about the nature of mathematics, their students interacted more within the mathematics class and explained their ideas more and in more depth. While past qualitative research has highlighted inconsistencies between teachers' beliefs and practice (Phillip, 2007) and other studies have explored the alignment of beliefs and teachers' notions of teaching (Cheng, 2009), there has been little quantitative analyses of the relationship between teachers' epistemological beliefs and teaching practice. This study filled that gap and confirmed the hypothesized positive relationship between more sophisticated epistemological beliefs and more student-centered discourse practices. Perhaps the construct of discourse, being an interactive phenomenon, is more intrinsically connected to the perceived nature of the discipline. That is, if a teacher believes math is about developing arguments, then the creation of those arguments resides in the discourse of the classroom.

Evidence that teachers' epistemological beliefs bare influence on their use of discourse accentuates the need for explicit attention to epistemological beliefs during teacher preparation and beyond. Just as teacher educators design tasks to increase MKT, this finding supports the creation of activities that allow teachers to grapple with their own beliefs about the nature of mathematics. Research has noted that teachers' beliefs are often difficult to change due to their experiences as students themselves (Philipp, 2002), and therefore collaboration is needed to cultivate experiences that will bring deep-set conceptions to the forefront and reconcile with new teaching theories. While research on epistemological beliefs has increased over the past years, more research is needed to better understand how to impact and sustain change. Also, exploration of the relationship between epistemological beliefs and MKT seems to be a powerful move within the field.

Efficacy. It was hypothesized that teachers' personal mathematics teaching efficacy (PMTE) would be a significant predictor of the level of MDC and EJ, however these hypotheses were not supported by this study. PMTE was not a predictor of either measure of discourse and this perhaps is due to the lack of specificity in the efficacy measure and the lack of variability of scores for the novice population. The MTEBI (Enochs, Smith, & Huinker, 2000) is a measure of mathematics teaching efficacy but it does not contain items specifically about leading discussions or questioning. Perhaps teachers can feel efficacious when thinking more generally about their mathematics instruction while being quite timid about their abilities to effectively utilize mathematical discourse. This sample also reported relatively high level of PMTE ($M = 54.58$), which is characteristics of novice teachers (Bates,

Latham, & Kim, 2011; Moseley & Utley, 2006) and therefore differences might not have been detected due to the limited range.

MKT. With the strongest theoretical backing for impacting teaching practice (Ball, Thames, & Phelps, 2008), MKT was hypothesized to predict both MDC and EJ. Although MKT did not predict the level of mathematical discourse community (MDC), this could be due to the fact that this measure of discourse is more focused on the social aspects of the student interactions. That is, MDC is measuring the opportunities for students to interact with the teacher and other students, and perhaps specialized content knowledge is not a prerequisite for this experience.

The EJ dimension attends to the frequency and depth of students' explanations; within this sample, teachers with higher MKT were more likely to ask students to explain their thinking and press for conceptual reasoning. Within the conceptualization of MKT, Ball and colleagues (Ball, et al., 2008) analyzed the work of teaching and all the responsibilities and skills that were involved; mathematical explanations are an essential part of teaching and therefore are a staple within the development of this knowledge construct. However, research exploring MKT and instruction has examined the mathematical explanations of the teacher (Hill & Charalambous, 2012; Steele & Rogers, 2012) and not explanations of the student. By probing students to explain their thinking, teachers gain access to students' misconceptions and strengths that would remain hidden otherwise. This study shows that even for novice mathematics teachers, when teachers have a stronger MKT, they tap into students' thinking more through open-ended questions than teachers who do not have this specialized type of knowledge. By shifting the lens to examine the students' opportunities for explanation, this

study moves beyond how MKT impacts the teachers' discourse and begins to address the question of how MKT influences classroom discourse.

Furthermore, the in-depth qualitative analysis and infographic visuals highlighted the lack of open-ended questions within the discussions of teachers with low MKT. The qualitative analysis revealed that while all teachers frequently engaged in patterns of literal questioning, teachers with high MKT inserted more probing questions to extend students' thinking and utilized less turns per minute. These findings from the quantitative and qualitative phases of the study add to the literature by presenting the relationship between MKT and a specific standards-based practice, mathematics discourse, for a novice population of teachers. Past research has been mixed in terms of the relationship between MKT and practice. Ottmar, Rimm-Kaufman, Larsen, and Berry (2015) did not find differences in teachers' standards-based mathematics practices; however, their conception of teaching practice was more holistic in that it measured elements of discourse along with tasks, representations, and lesson structure. The relationship between MKT and discourse may have been "washed out" by the various components of teaching practice that were examined. This study allowed for close examination of the interactions and opportunities for students to engage with the mathematics through discussion.

This study opens a new window into the classrooms of novice elementary teachers by examining their mathematics discourse at multiple levels. Findings support the continued efforts within mathematics content and methods courses to increase pre-service teachers' MKT and professional development efforts to extend learning past preparation programs. Teacher educators bear the responsibility of preparing teachers to effectively teach

mathematics, but this effectiveness extends past accuracy and includes standards-based practices such as discourse strategies. This study shows that if teachers know “of the mathematics” and not just “about the mathematics” (Ball et al., 2008) they are more likely to engage in practices that promote standards-based discourse practices.

Limitations

The key limitations of this study are centered on the novice population, recorded mathematics observations, school context variables, and belief constructs.

First, this study’s participants were novice elementary teachers that were propensity score matched on college entry characteristics indicating they were successful high school graduates and above average in terms of academic achievement (average high school GPA = 4.25; average SAT/ACT = 1095/22.2). The homogenous population allows for comparison within the sample, however, generalization should not be made to other teacher populations. Future work should expand the examined population to investigate the impact of entry-level characteristics on MKT and other teacher attributes that were statistically significant predictors of the level of discourse.

Also, while third-party observation is often cited as the “gold star” of classroom research (Rowan, Camburn, & Correnti, 2004), this study employed observations of recorded lessons as a solution to time and financial constraints. Although thorough attention was given to training teachers on effective recording strategies, teachers were not able to capture their instruction in a way that would parallel video recordings by a trained videographer. For this reason, some small group work is not easily heard or seen. To attend to this limitation, observers indicated if the audio or visual hindered their coding a lesson with the M-Scan. The

tagged lessons were not utilized in the analysis. Furthermore, there is disagreement within the field about the adequate number of observations needed for a reliable estimate of classroom practice (Mashburn et al., 2014). While past research with the M-Scan (Walkowiak, 2010) indicated low variation within teacher, this sample of novice teachers is a unique sample. Future work is needed to determine the number of observations needed to reliably analyze teaching practices of novice teachers.

Additionally, the conceptualization of school context is limited within this study. The construct of perceived support for mathematics was measured through a Likert-scale survey that, while attending to important opportunities for professional development and planning, did not attend to specifics about standards-based mathematics or discourse practices. That is, while a teacher might report feelings of support for mathematics in a general sense, they might not feel supported in their use of student-centered discourse practices that might seem unstructured to administrators.

Lastly, amidst the ongoing dialogue of epistemology, it is important to acknowledge that the measure used to characterize teachers' epistemological beliefs was a self-report measure. The MECS (Jong, et al., 2013) measure is a promising instrument that provides a multi-faceted examination of dispositions, confidence, and beliefs. Only the beliefs subscale was used within this study. Additional interview data would strength the conceptualization of this construct and provide a better link to practice. Furthermore, the efficacy measure utilized in this study was content-specific but not specific to discourse or standards-based practices. Literature supports the need for domain-specific measures of efficacy; however, such instrument was not available for mathematical discourse.

Future Research

The findings from this study promote future research on classroom mathematical discourse. First, further work is needed to better understand the classroom discourse practices and how they differ for classrooms of varying SES. The statistically significant relationship between FRPL and MDC was not fully explained within the parameters of the qualitative phase, and an alternative analysis is needed. By sampling based on FRPL, additional lessons can be qualitatively coded using the dimensions of the MDC construct (solicitation of student ideas, student-to-student talk, and open-ended questions) to compare and contrast the experiences of students in different contexts. Furthermore, a more qualitative analysis of entire lessons will provide a more detailed examination of the grouping structures and opportunities provided to different groups.

Another line of research revolves around the ATM coding framework. Several additions were proposed in the discussion section, and these augmentations will be designed and tested with other lessons within the sample. The addition of revoicing and turn-and-talk moves will allow for future application of the coding scheme that aligns with current pedagogies taught in elementary mathematics methods courses. Strategic sampling based on the EJ scores from the M-Scan coding will allow for variance in the discussions and set the stage for continued validation of the ATM measure. The convergence and divergence between the two measures will be analyzed, and additional work will be completed to explore the use of both measures as alternate forms of observational feedback.

Also, as summoned by Resnick, Asterhan, and Clarke (2015) research is needed to bridge the gap between discourse practices and student learning. While the mathematics

education field endorses the use of high-quality discourse (CCSSM, 2010; Micheals & Connor, 2010), there is little evidence of its impact on student learning in the form of student achievement scores. Perhaps future research that can provide a link between practice and student achievement will bring non-supporters on board and strengthen the field's resolve to ensure that teachers around the country are engaging students in high-quality discourse. Paramount to these lines of research, collaborative efforts should be made to continue the work of Scherrer & Stein (2013) to utilize the ATM framework as a tool for professional development and teacher preparation. As the mathematics education field strives to make high-quality discourse a norm in elementary classrooms, additional resources are needed to support teachers' development of practice. The ATM framework provides a tool for teachers to use in analysis of their practice focused on the positioning of students in the conversation. Infographics allow teachers to "see" how they are positioning students and where they can transfer power to students by engaging in certain moves. These moves can then be rehearsed or practiced to promote actualization of the practice.

Conclusion

This mixed methods study revealed relationships between novice teachers' attributes, along with school context, and the mathematics discourse in their classrooms. This window into the novice elementary teachers' classroom is needed as the field struggles to understand why decades of reform are not making a lasting impression on classroom communities of practice. This study found that teacher attributes and school context bear influence on the types of mathematics discourse that are occurring in mathematics classrooms, and therefore emphasizes the need to attend to the teacher's distinct characteristics and the school culture

when attempting to impact change in classroom practice. If children are to engage in authentic practices of mathematicians such as justifying their reasoning and critiquing others, their teachers need opportunities to cultivate discourse moves that will prompt such interactions. Through systematic practice with discourse moves, it is proposed that teachers will increase their use of more open-ended moves and venture away from the repetitive use of literal questioning techniques.

Lastly, while this research opens a window into novice teachers' classrooms more work is needed to better understand the opportunities for mathematical discourse provided to students with varying socioeconomic backgrounds. The variance in the mathematical discourse community attributed to FRPL is something that beckons further investigation. Through collaboration among teacher educators, professional development facilitators, and teachers further research can be conducted to better understand the communities of practice within various school contexts. As a result of these collaborations, strides can be taken to ensure that all children are learning in environments that empower them to be active participants in the mathematics discourse.

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Appendix A

Mathematics Scan (M-Scan) Discourse Dimensions

Mathematical Discourse Community			
	Low (1,2)	Medium (3, 4, 5)	High (6, 7)
Teacher's Use of Discourse	The majority of math discussion in the classroom is directed from the teacher to the students. Teachers are wholly responsible for the content of the math discussions.	Some of the math discussions in the classroom included student participation, but some is teacher-initiated. Teachers are partially responsible for the contents of math discussions.	Throughout the math discussion in the classroom, students consistently participate. Students play a substantive in directly the content of math discussions.
Sense of Mathematics Community through Student Talk	When students talk, they rarely share mathematical ideas and language. Student to student talk rarely or never occurs.	When students talk, they sometimes share mathematical thinking and language. Student to student talk sometimes occurs.	When students talk, they often share mathematical thinking, and language. Student to student talk frequently occurs.
Questions	All of the teachers' questions have known/correct answers. Students' ideas, questions, an input are rarely or never solicited.	Most of the teacher's questions have known/correct answers, but some are focused on mathematical thinking. Students' ideas, questions, and input are sometimes solicited.	Some of the teacher's questions have known/correct answers, but many are focused on mathematical thinking. Students' ideas, questions, and input are frequently solicited.

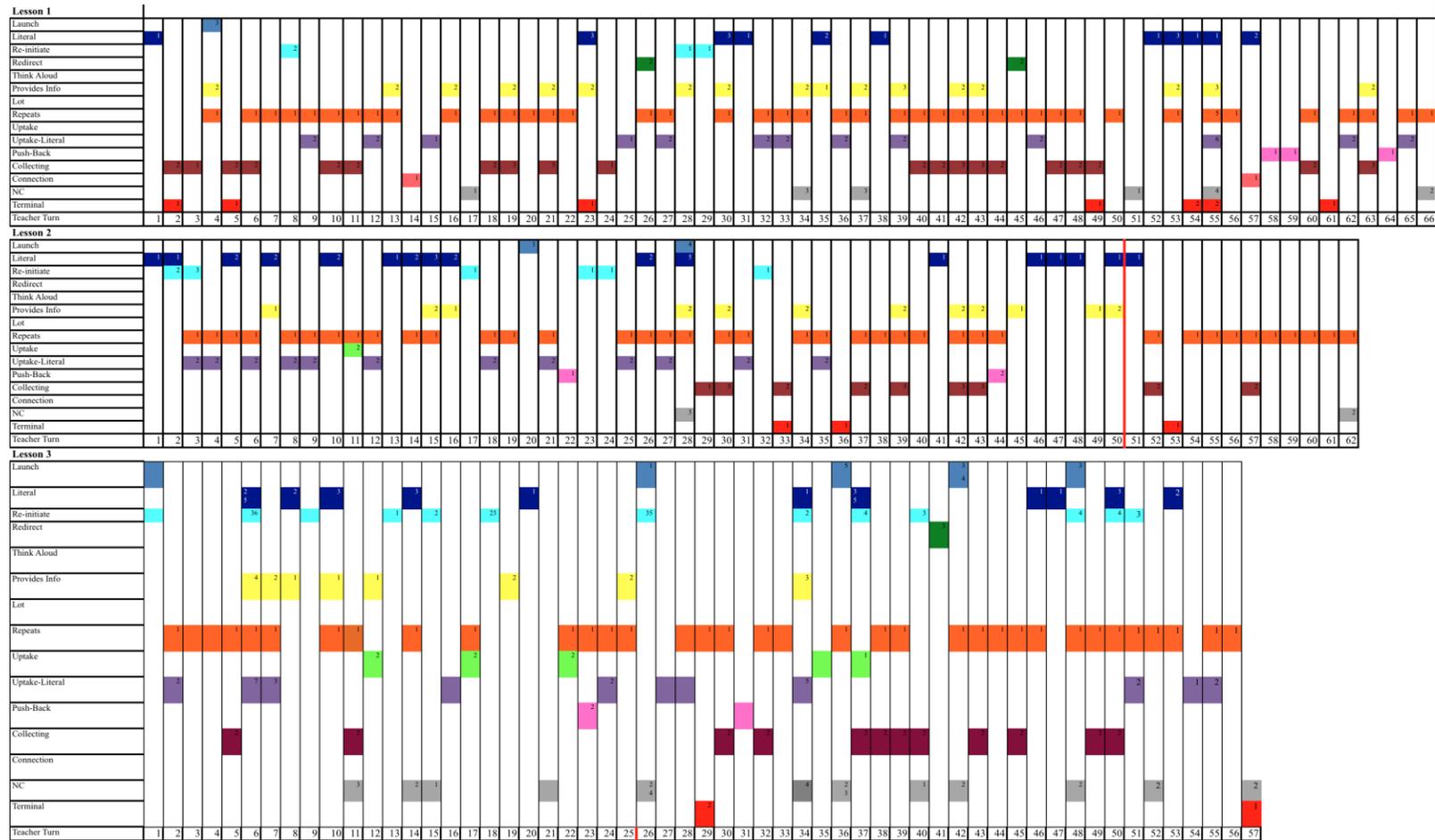
Berry, R. Q., Rimm-Kaufman, S. E., Walkowiak, T. A., McCracken, E. R., Merritt, E. G., & Pinter, H. H. (2010). *The Mathematics-Scan Coding Guide*. Unpublished measure.

Explanation and Justification			
	Low (1,2)	Medium (3, 4, 5)	High (6, 7)
Presence of Explanation and Justification	Students rarely provide explanations or justify their reasoning Teachers rarely ask “what, how, why” questions or otherwise solicit student explanations/justifications.	Students sometimes provide explanations and/or justify their reasoning. Teachers sometimes ask “what, how, why” questions or otherwise solicit student explanations/justifications.	Students often provide explanations and/or justify the reasoning. Teachers often ask “what, how, why” questions or otherwise solicit student explanations/justifications.
Depth of Explanation and Justification (procedural and conceptual)	Student explanations often focus on procedural steps and <i>rarely</i> include conceptual understanding of the topic(s).	Student explanations sometimes focus on procedural steps and <i>sometimes</i> include conceptual understanding of the topic(s).	Student explanations rarely focus on procedural steps and <i>often</i> focus on conceptual understanding of the topic(s).

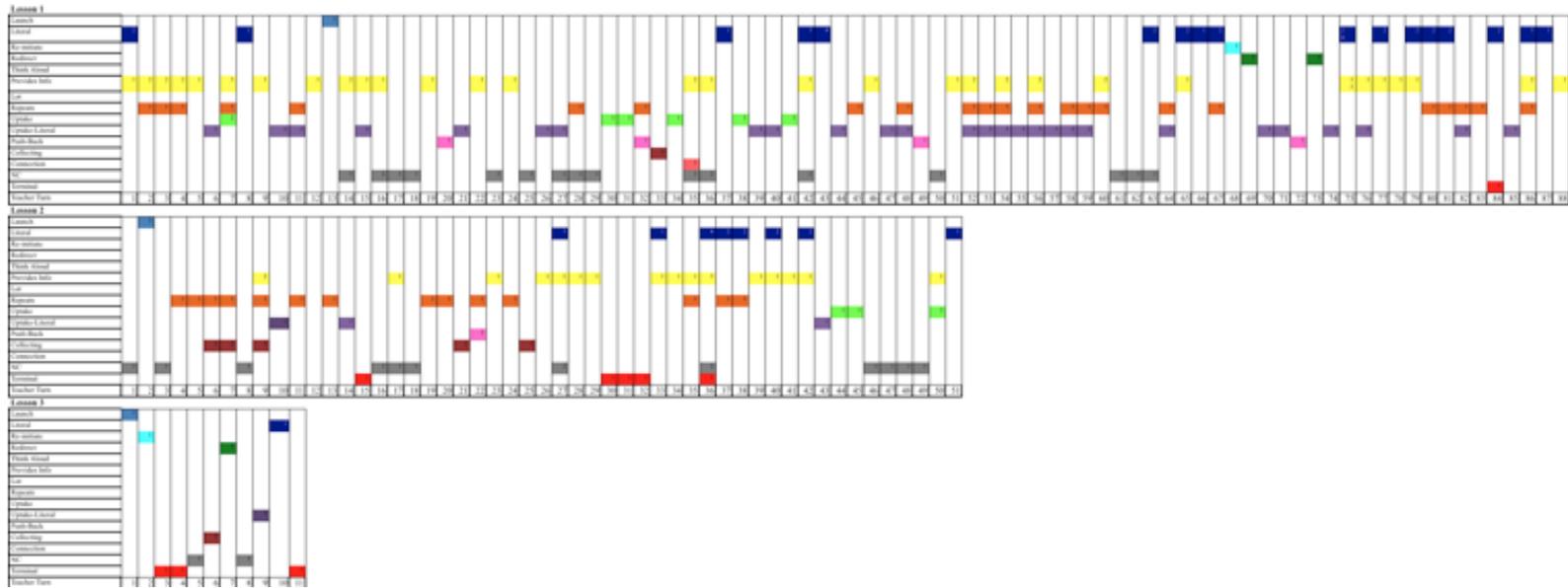
Berry, R. Q., Rimm-Kaufman, S. E., Walkowiak, T. A., McCracken, E. R., Merritt, E. G., & Pinter, H. H. (2010). *The Mathematics-Scan Coding Guide*. Unpublished measure.

Appendix B

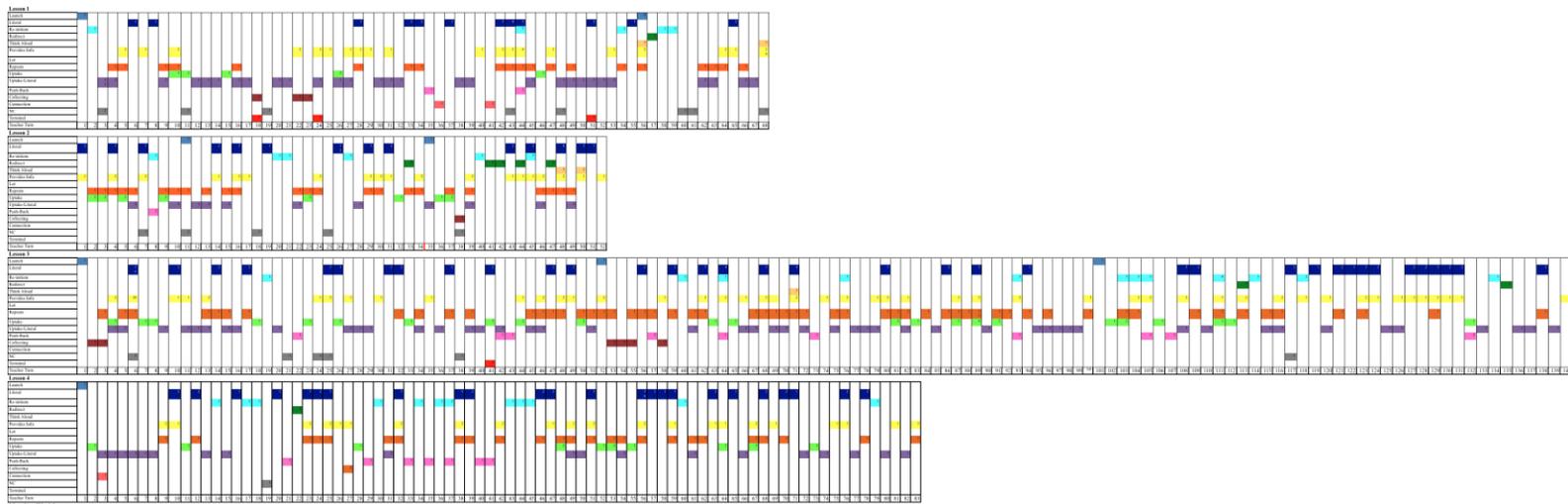
Infographics of Teachers' Lessons/Discussions



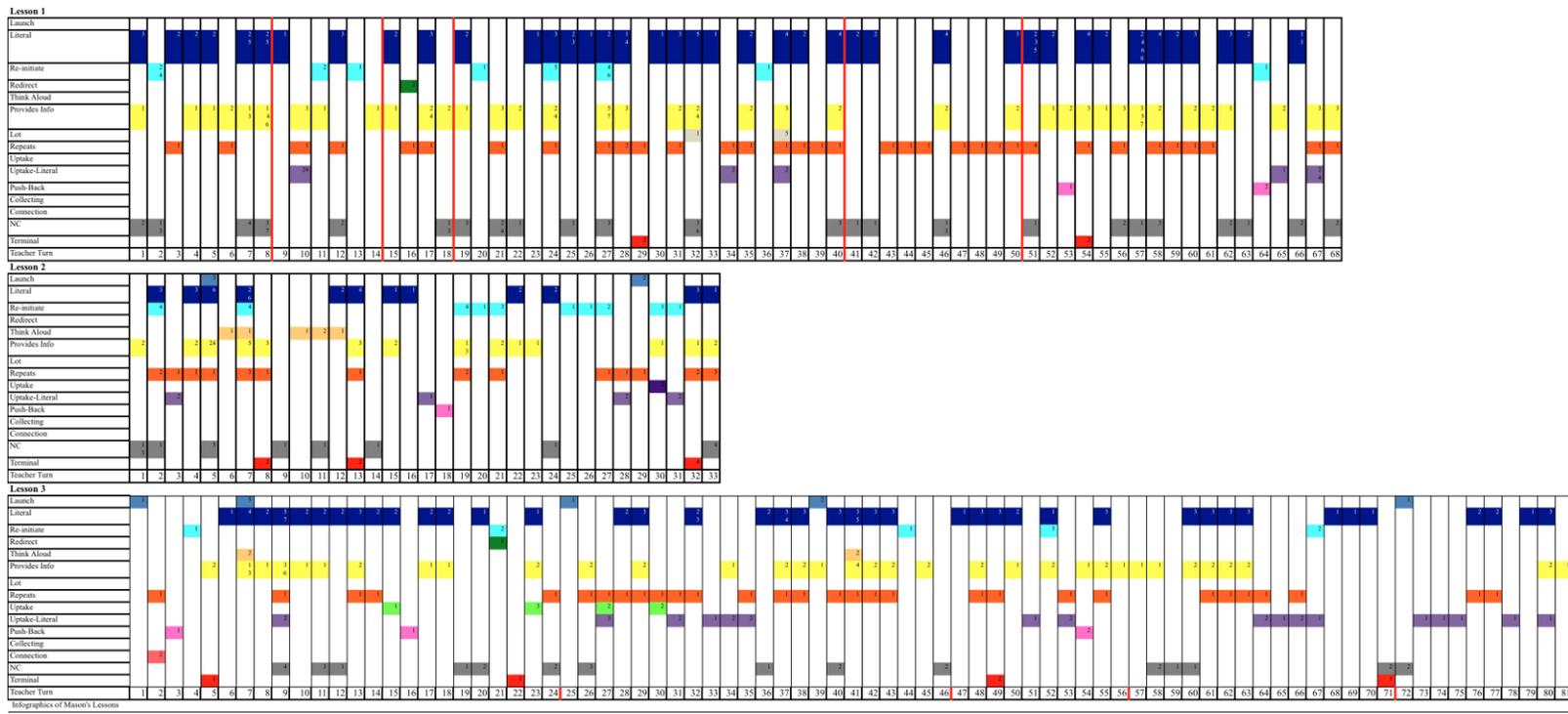
Pictures of Lindsey's Lessons



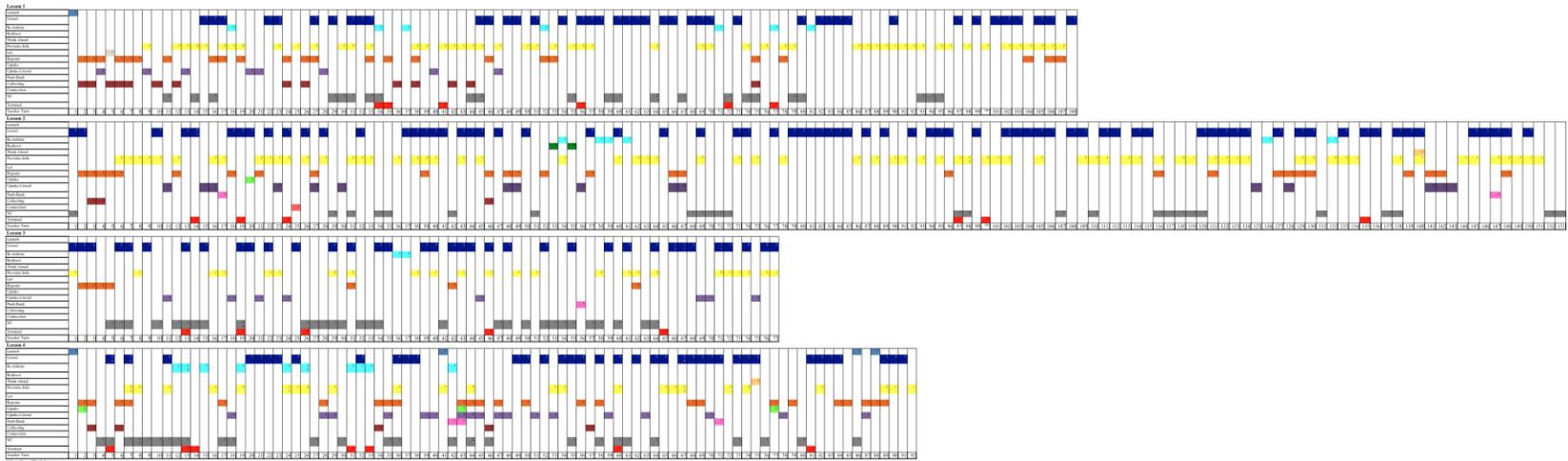
Pictures of Mikel's Lessons



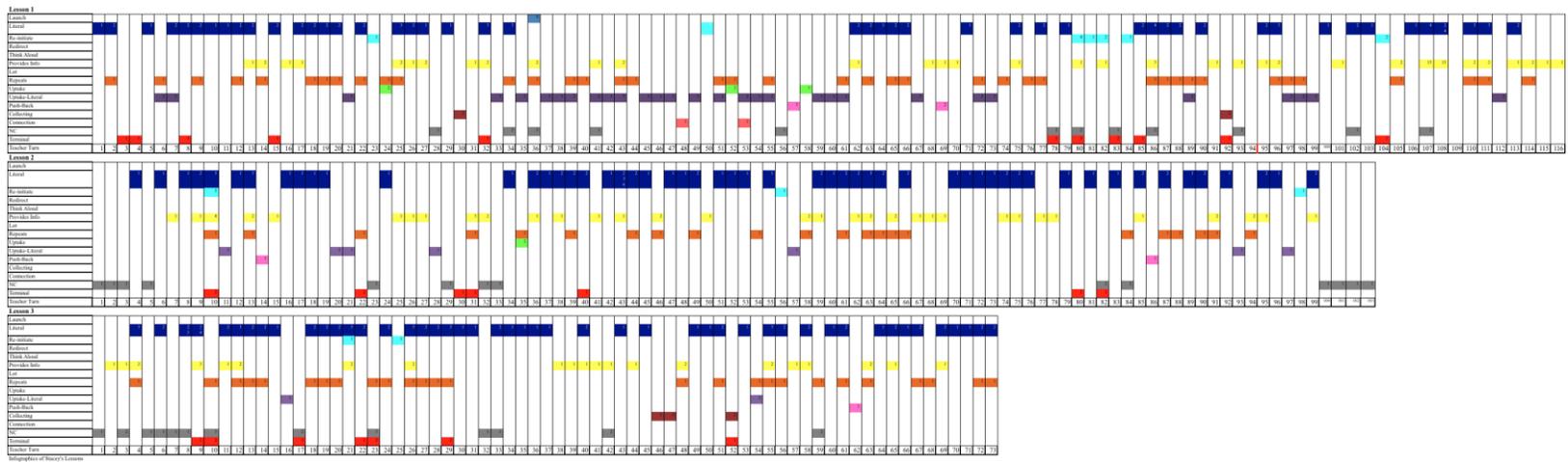
Pictures of Mona's Lessons



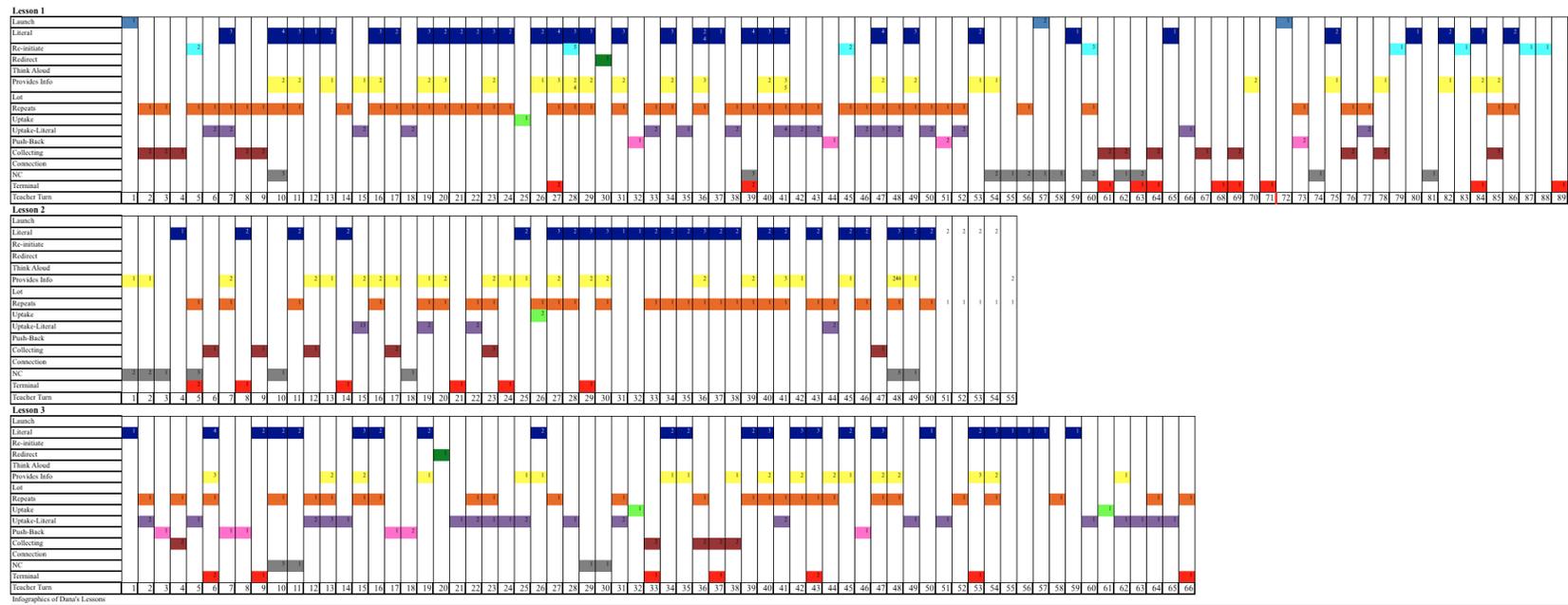
Pictures of Mason's Lessons



Pictures of Keri's Lessons



Pictures of Stacey's Lessons



Pictures of Dana's Lessons