The Evolution of Contextualized, Discourse-based Professional Development to Support Elementary Teachers in the Implementation of Conceptual Mathematical Teaching Practices

Jennifer Aren Kueter

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The Evolution of Contextualized, Discourse-based Professional Development to Support Elementary Teachers in the Implementation of Conceptual Mathematical Teaching Practices

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Dedication

This work is dedicated to my family, who has always supported and encouraged me. My mom is my role model, the example of the kind of teacher and person I want to be. My dad taught me to connect with people, openly listen to their stories, and connect with their lives. My husband, Joe, kept things going while I locked myself in a room to work and type. My sisters, Karen and Brenda, supported and encouraged me throughout the process. My children, Morgan and Taylir, motivated me to make the world of education a better place so they, and my grandchildren, can have a better world. I thank Dr. Miller, who guided me through this process and was there each time I had a “freak out,” You were always there when I needed help and encouragement. I could not have finished this without you! To my family and friends, especially my cohort partner Halley, who edited parts of this document, your input was vital to my success. To my participants….. Thank you for going through this 2-year process with me. Thank you for believing in my passion, dedicating your time to change your teaching, and jumping in with both feet allowing me into your classroom and lives. I hope you gained as much from this process as I did. And finally, this work is dedicated to every elementary teacher. May this research be the data needed to encourage districts to give you PD and support when asking you to do “one more new thing”!
Abstract

This holistic, mixed-methods action research case study aimed to determine the influence of professional development on participants' mathematical teaching practices and how the changes influenced students' opportunities for discourse. In this two-year study, participants engaged in two professional development phases and implemented new conceptual teaching practices. Quantitative data were collected through surveys and observations. Qualitative data were collected through observations and interviews. Phase-one findings showed that while teachers changed their practices, they were not proficient in conceptual and discourse-based teaching practices. A second phase of professional development occurred using a Community of Practice model. Phase-two findings showed conceptual teaching practices were now a regular part of participants' routines, and students were provided with multiple opportunities for dialogic discourse throughout their school day. Findings from this study add to the growing body of research on the need for contextualized, ongoing professional development to implement conceptual-based mathematical practices.
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Chapter 1: Introduction

The need for science, technology, engineering, and mathematics (STEM) education has become more prevalent in the elementary classroom, with national reports calling for changes in how these subjects are taught ([NAEP, 2019; National Research Council [NRC], 2012; National Science Board, 2010). An Integrated STEM education that extends throughout K-12th grades can contribute to scientific and technological literacy, two essential attributes of productive citizens (National Academies Press [NAP], 2010). However, there is no single definition of what STEM education is or should be (Breiner et al., 2012; Holmlund et al., 2018; Larson, 2017). What has been shown is that STEM learning promotes the integration of subject areas, learning connected to real life, problem-solving, and active engagement in rigorous learning (Holmlund, 2018). Mathematics is an essential foundational skill in STEM education and vital for successful STEM understanding (Breiner et al., 2012; Larson, 2017). Teaching students to reason, understand, and discuss mathematics can lead to the development of successful STEM students (Larson, 2017). The reasoning developed in mathematics supports overall cognitive development, creates positive STEM attitudes, and can predict later school success (Clements & Sarama, 2016).

As an elementary school student, mathematics was easy for me. I memorized my mathematics facts, followed the procedures, and got the correct
answers. I was not a quiet child, and the teachers often sent me to the hallway alone to work at my own pace, so I would not bother those around me. I enjoyed this as it made me feel smart; I did not need help. However, as I entered high school, mathematics became more difficult. Problems became more challenging, and I needed more than a rule to follow to find the solution. Working through a mathematics workbook alone did not help me learn how to problem solve, apply my learning to new situations, or analyze a mathematical situation. I still needed to learn how to participate in productive mathematical discourse. To me, mathematics was procedural and rote. I purposefully chose easier mathematics courses in high school so I would never have to take calculus. I worried it would be too difficult. Mathematics courses that required more than memorization were a barrier, as I needed to learn how to navigate deeper conceptual thinking around mathematical concepts.

When I became an elementary teacher, I was excited to teach mathematics. I knew elementary mathematics. It was “easy mathematics,” and I wanted to share that joy with my students. When I began teaching, I found myself instructing students who had not developed number sense, struggled to memorize facts, and did not know how to follow multi-step directions. They needed to build their number concepts and mathematical understanding, but I lacked the necessary tools and skills to teach these concepts. All those years of sitting in the hallway alone did not help me learn how to explain my thinking to others.
When I took a preservice mathematics education class in the 1990s, it did not include learning or teaching through productive discourse. Productive discourse is a classroom conversation, with the teacher as the facilitator for students as they talk with and to each other about their mathematical thinking (Smith & Stein, 2018; Walter, 2018). My classwork focused on creating units and teaching procedures, the current preservice mathematics education of that time. Several years into my teaching career, I had yet to learn how to share my mathematical understanding with my students or teach them to do the same. This issue was compounded when the Common Core State Standards for Mathematics (CCSS-M, National Governors Association Center for Best Practices, Council of Chief State School Officers [CCSSO], 2010) were adopted by my school district.

The CCSS-M learning goals for students at each grade level stress a need for conceptual understanding and procedural skills (Murata et al., 2012; NCTM, 2014). The Standards of Mathematical Practices (SMP) (CCSSO, 2010) are vital to the CCSS-M (see Appendix A). These standards aim to develop conceptual understanding and engage all students in meaningful mathematics through problem-solving, communication, and argumentation (Bennett et al., 2014; CCSSO, 2010; Hamilton et al., 2016; Osana et al., 2011). When using SMPs, students learn to be successful thinkers and develop complex thinking processes. These skills often encourage interest in STEM careers (Bennett et al., 2014; Cook, 2017; NTCM, 2014). Conceptual understanding involves comprehending mathematical concepts, operations, and relationships
(Allensworth et al., 2021; Bennett et al., 2014; Kilpatrick et al., 2001). It is not simply memorizing what to do but understanding the meaning behind what to do.

When using SMPs, students must learn to make sense of problems, construct arguments, and reason abstractly, skills necessary in all STEM domains (NGAC, 2010; NTCM, 2014). I had not learned mathematics using these standards and needed to learn how to apply them to my teaching. I needed Pedagogical Content Knowledge (PCK) to teach conceptual mathematics. I needed professional development (PD) to develop PCK so I could teach and learn mathematics differently. My district offered no training, so I attended mathematics conferences to improve my mathematical understanding with the hope that it would enhance my instruction.

During the 2018 and 2019 school years, I attended several National Council for Teachers of Mathematics (NCTM) conferences. My conference sessions focused on using productive discourse and implementing mathematical discourse with students. The resources and knowledge I gained from this training inspired me to change my mathematics instruction. Seeing examples of students engaged in discourse and the mathematical understandings they could express was inspiring. I began a shift towards more student-centered, discourse-based learning in my teaching. When adding discourse into my daily routines, I was amazed at the difference in my students’ thinking, learning, and problem-solving. As their mathematical understanding increased, so did their ability to solve more complex mathematical problems and explain their thinking to others. The joy in mathematics was no longer when my students found mathematics easy but
rather when they found how fun it was to “play” with numbers and find the relationships between them.

Through conversations with my colleagues about their mathematics instruction, I found that many felt as I previously had. They did not understand how to apply the SMPs in their classrooms, so many just “followed what the book said” or “did what we always did” and hoped their kids would be successful. My colleagues needed PD to develop their PCK to teach conceptual mathematics and had not been given this opportunity in my district. Unfortunately, test scores and students’ mathematical progress show that, as a state, we are not advancing our students’ mathematical thinking or problem-solving in Alaska (NAEP, 2019). Data from the 4th and 8th-grade NEAP mathematics assessments showed no significant difference in state mathematics test scores between 2003 and 2019 (NAEP, 2019). In my past experiences as a teacher leader in the district’s mathematics academic alignment committee for six years, I have observed that many teachers struggle to access training opportunities unless presented through the school or district. Living in Alaska means teachers often must travel long distances to receive professional development, as our district does not provide many quality opportunities. Many teachers in my school have communicated that they want and need to improve their mathematics teaching but are unsure how to adapt their teaching practices to the new methods of conceptual mathematical learning (Jansen et al., 2017).

With my district’s adoption of a new standards-based mathematics curriculum, Ready Mathematics (Curriculum Associates, LLC, 2020), there was
again a need for additional training. This new curriculum focuses more on the SMPs, specifically teaching conceptual learning through student discourse. The SMPs concentrate on how mathematics works and what it means to “do” mathematics (Killpatrick et al., 2016; NCTM, 2014). The teachers in my building had already expressed concerns about their lack of skills to implement this new curriculum successfully. Using discourse and conceptual learning is not how most teachers learned mathematics or how to teach mathematics (Kutara et al., 2018; Ni et al., 2021; Sztajn et al., 2020). The district provided a one-day introductory training, but teachers need ongoing professional development (Desimone, 2009; Kennedy, 2016; Polly et al., 2014). The one-day training focused on access to resources and following the daily plan; there was no support for using discourse or explanation on conceptual mathematics. To change the mathematical education of our students, we need to change how we prepare teachers so they are confident and ready to support their students in this new learning style (Gee & Whaley, 2016; Gellert, 2012; Guskey, 2003).

Problem of Practice

The problem of practice surrounding this research was the need for more effective professional development available for teachers as they transitioned to discourse-based mathematics teaching practices (Desimone, 2009; Kutaka et al., 2017; Polly et al., 2015). Research has called for the implementation of conceptual and discourse-based approaches to teaching and learning mathematics (Harbour & Denham, 2020; Seago et al., 2016; Xin et al., 2020). For this shift to occur, teachers must gain mathematical knowledge and teaching
experiences in these conceptual approaches to mathematics (Boaler, 2018; Gomez Zwiep & Benken, 2013). As many teachers are unfamiliar with conceptual and discourse approaches, PD is needed to support the knowledge and skill acquisition necessary to successfully implement productive discourse teaching practices in their classrooms (Osana et al., 2011; Smith & Stein, 2018; Svendsen, 2020). Learning to facilitate productive discourse requires new teaching practices, which can be challenging for teachers as they must develop new skills to facilitate conversations and support students in explaining, justifying, and critiquing ideas with peers (Harbour & Denham, 2021; Heyd-Metzuyanim, 2019; Michaels & Connor, 2015). To make this learning effective, PD should be grounded in the daily lives of teachers and their students, allowing teachers to apply the skills and knowledge they learn directly in their classrooms (Lave & Wenger, 1991; Ni et al., 2021). This study explored how ongoing, contextualized PD can support elementary teachers in navigating discourse-based teaching and its influence on students' mathematical discourse opportunities during instruction.

**Background**

**Need for Professional Development**

It is widely accepted that PD can improve teaching (Brandefur et al., 2020; Guskey, 2003; Desimone, 2009; Kennedy, 2016). However, not all teachers believe that PD helps them prepare for reforms in teaching (Perry et al., 2015). PD is often presented to teachers in a top-down approach as part of a mandated change with required information presented by experts (Svendsen, 2020). Traditional PD is often segmented and underestimates what is needed to
translate learning into instructional change (Desimone, 2009; Kutaka et al., 2016). Often, it is conducted outside the classroom and disconnected from the changes needed inside the classroom (Kennedy, 2016). Teachers are often told what to do instead of being given the tools and allowed to decide how to implement them in the classroom (Svendsen, 2020). For changes in practice to occur, teachers must enact new practices within the context of their classroom and be able to see their impact on student outcomes (Desimone, 2016; Guskey, 2003; McGee et al., 2013). For PD to be effective, it must be grounded in the daily lives of teachers and focused on improving their teaching in their classrooms (Kennedy, 2016; Kutaka et al., 2016; Svendsen, 2020).

The CCSS-M (CCSS, 2010) for mathematics addresses a necessary change in the content learned in K-12 mathematics and how mathematical content should be delivered for student success in mathematics. (Letwinsky & Cavender, 2017; NCTM, 2014). The SMPs (see Appendix A). are part of these standards and focus on how mathematics works and what it means to “do” mathematics (Killpatrick et al., 2016; NCTM, 2014). Professional Development is the key to implementing these teaching practice changes (Guskey, 2003; Desimone, 2009; Sykes, 1996; Sztajn et al., 2020). Teachers need current PD contextualized around their classroom to develop mathematical content knowledge and engage in personal growth (Gomez-Zwiep & Benken, 2013; Kutaka et al., 2017; Osana et al., 2011). They need the opportunity to relearn mathematics using strategies their students must use to learn mathematics (Burns, 2007; Seago, 2016). The knowledge for teaching mathematics must
include an understanding of student thinking and the ability to provide developmentally appropriate support (Darling-Hammond, 2017; Ni et al., 2021; Polly et al., 2015). According to Gellert (2102), teachers are more apt to change their thinking and practice when they have opportunities to learn about and discuss student thinking about mathematics. Teachers must understand how and why to teach conceptually before successfully implementing conceptual learning in their classrooms (Heyd-Metzuyanim et al., 2019).

For teachers to be adequately prepared to engage in the use of productive discourse in the classroom, they must have the opportunity to engage in quality PD, where they learn how to incorporate discourse-based pedagogy in ways that support students' conceptual understanding (Gee & Whaley, 2016; Gellert, 2012; Murata et al., 2017; Murphy, 2015). The current study took the research one step further by looking at the influence of a contextualized community of practice (CoP) professional development on participants' implementation of a standards-based mathematics curriculum and changes in opportunities for student discourse during instruction.

**Community of Practice**

A CoP is created when a group engages in collective learning with a shared topic of interest and a commitment to collective competence (Wegner & Wegner, 2015). By “thinking together,” participants can guide each other to a deeper understanding (Pyrko et al., 2017, p.391) and develop new knowledge and expertise through their interactions (Olanoff et al., 2021). Teachers develop learning communities to change and reflect on their teaching practices (Gellert,
A community of practice transforms PD from a top-down approach to one where teachers are seen as learners and contributors to the knowledge base (Buysse et al., 2003; Olanoff et al., 2021).

**Importance of Conceptual Knowledge**

Conceptual knowledge is understanding the relationship between mathematical concepts, procedures, and operations (Jansen et al., 2017; NRC, 2001). It instills deeper learning and long-lasting mathematical understanding (Crooks & Alibali, 2014). Through the SMPs, the CCSS-M supports student learning to apply mathematical knowledge when evaluating which procedure to use in flexible problem-solving, generalize their knowledge to a new situation, and determine if a solution is reasonable (NCTM, 2000; Crooks & Alibali, 2014). Alternatively, traditional approaches focus on mathematical procedures (Jansen et al., 2017). Conceptual understanding is essential in STEM education because it develops students’ abilities to provide evidence, reason, and interpret mathematical knowledge, skills necessary for applying mathematics in real-world situations (Jansen et al., 2017; NRC, 2001). Conceptual understanding deepens student understanding through connections and applications of mathematical concepts (Crooks & Alibali, 2014; Jansen et al., 2017).

**Use of Discourse**

Effective conceptual mathematics teaching and learning requires teachers to change traditional teaching practices significantly and develop a discourse community in their classrooms (Murata et al., 2012; Murphy, 2015; NCTM, 2000). Traditional mathematical teaching practice is often characterized by the teacher
presenting a concept to the class, showing the procedure for solving it, and then having the students practice using the same procedure (Brandefur et al., 2021; Chapko & Buchko, 2004). These traditional methods use direct forms of instruction, require lower-level thinking, and are teacher-centered (Cook, 2017; Kutaka et al., 2018; Walter, 2018). In contrast, a discourse-based, conceptual approach involves students looking at a problem, knowing multiple ways to solve it, and sharing their thinking and solution strategies (Boaler, 2018; Brandefur et al., 2021; NCTM, 2014). To develop conceptual understanding, students need the opportunity to share their ideas through productive mathematical discourse and consider the perspectives of their peers (Baxter et al., 2002; NCTM, 2014; Murphy, 2015).

Discourse-based learning is crucial in building student conceptual understanding (Ho et al., 2019; Kutaka et al., 2017; Lampert, 1990; Smith & Stein, 2018). Discourse makes students' mathematical reasoning visible, allows for open reflection, and provides opportunities for students to reason, defend, and prove their conceptions to others (Hufferd-Ackles et al., 2004.; Mercer & Sams, 2008; Walter, 2018). Discourse changes the construction of mathematical knowledge into a joint venture of a class instead of communication solely from teacher to student (Lampert, 1989; Reznitskaya & Gregory, M. 2013; Sfard, 2007). When discussing mathematical ideas and listening to others, students can think deeply about mathematics and engage in SMPs of justifying, noticing, explaining patterns, reasoning, and evaluating arguments (Hufferd-Ackles et al., 2004; Lampert, 1990; Murata et al., 2012). These practices do not just benefit
mathematical learning and are vital components of all STEM domains (Bennett et al., 2014; Cook, 2017). Students who can talk and think mathematically are more apt to use those skills in other STEM subjects (Larson, 2017).

**Productive Discourse**

Productive mathematical discourse is “the purposeful exchange of ideas through classroom discussion, as well as other forms of verbal, visual, and written communication” (NCTM, 2014, p. 24). It is not about answering questions from the teacher but rather an opportunity for students to share and justify their thinking and engage in mathematical conversations (Ho et al., 2019; Kutaka et al., 2017; Smith & Stein, 2018; Walter, 2018). However, teaching with productive discourse can be a challenge for many teachers as most did not learn mathematics using discourse-based strategies (Smith & Stein, 2018; Walter, 2018). Productive discourse does not happen accidentally; teachers must learn to design and facilitate a learning environment where students use discourse to engage in high-quality mathematical tasks to discuss ideas and refine their thinking (Harbour & Denham, 2021). Smith & Stein (2018) share five practices to support teachers in facilitating mathematical discourse (p 9-10):

1. **Anticipating** possible student responses to challenging mathematical tasks and planning questions to ask students to produce them;
2. **Monitoring** students’ responses to the tasks while they are problem-solving;
3. **Selecting** specific students to present their mathematical work during the whole class discussion;
4. **Sequencing** the student responses to be shared and discussed in a particular order.; and

5. **Connecting** students’ responses to each other and vital mathematical ideas.

These Five Practices were used as a guide for developing the PD for the first phase of this two-phased research study. The practices support teachers and make the transition to conceptual-based mathematics more manageable by providing teachers with a framework to structure their lessons and guide student thinking (Harbour & Denhman, 2021).

**Ready Mathematics Curriculum**

Curriculum Associates, LLC created the *Ready Mathematics* K-5 program to assist teachers to “create a rich classroom environment in which students at all levels become active, real-world problem solvers. Through teacher-led instruction, students develop mathematical reasoning, engage in discourse, and build strong mathematical habits.” (Curriculum Associates, 2020, para. 1). This curriculum developed lessons based on the SMPs, specifically focusing on using discourse. *Ready Mathematics* K-5 encourages students to develop deeper understandings and make connections to prior learning and between mathematical concepts (Curriculum Associates, 2020). This research-based curriculum was adopted by the participating school district in 2020, with implementation to begin in the 2021-2022 academic year. Research shows that *Ready Mathematics* K-5 follows CCSS rigor and supports conceptual mathematical learning (Swain et al., 2019). With the adoption, Curriculum
Associates requires a mandatory one-day training session that teachers must complete before using the curriculum. This training focused on the program’s core components and resources, including the teacher’s toolbox, assessments, and intervention activities.

**Research Questions**

Using a holistic, mixed-method case study approach, this action research case study explored the following research questions:

1. How does teacher participation in discourse-focused professional development influence conceptual teaching practices?
2. How does teacher participation in discourse-focused professional development influence student discourse during instruction?

**Theoretical Framework**

A theoretical framework is integral to action research as it is the foundation for the research methods and data analysis (Osanloo & Grant, 2016). This study is grounded in two theoretical frameworks: sociocultural theory and commognition. Sociocultural theory focuses on the idea that learning is collaborative, and we gather knowledge through communication (Vygotsky, 1978), the foundation of the professional development portion of the research. Commognition focuses on the idea that mathematical learning is a form of discourse (Sfard, 2007) and was a foundation for the discourse part of the study. Through these theoretical lenses, this research explored teacher-researcher-designed and discourse-centered professional development in elementary
mathematics teaching and learning. While situated learning theory (Lave & Wenger, 1991) could also apply to this research, it was not selected as the PD was not situated in the classroom but contextualized to the teacher’s individual needs.

**Sociocultural Theory**

Sociocultural theory is the first theoretical framework for the study. Sociocultural theory stresses the importance of learning through interaction and collaboration (Scott & Palincsar, 2013). Learners gain deeper mathematical understandings when they share their ideas and listen to others’ reasoning and ideas (John-Steiner & Mann, 1996; Steele, 2001). It is the development of thoughts created through communication that develops learning (Vygotsky, 1987). For this learning to occur, learners must participate in joint activities, and through their communication and collaboration, they will acquire new knowledge and mathematical strategies (Scott & Palincsar, 2013). Vygotsky (1994) stated that communication is a cultural tool, and individuals learn the meanings of that culture, in this case, mathematics, through our discourse with each other. Therefore, teachers need to know how to help students effectively share their ideas to provide a stronger foundation for classroom communication (Steele, 2001). Sociocultural theory is connected to both research questions as it provides a means to describe discourse and how it influences participant and student discourse.

In addition to collaborative learning, Vygotsky (1978) emphasized the idea of the zone of proximal development. The zone of proximal development (ZPD) is
essential for teacher and student learning. The ZPD focuses on how learning needs to be matched to the learner’s development (John-Steiner & Mann, 1996; Scott & Palincsar, 2013). This learning place is between the learner’s present and potential understanding (Vygotsky, 1978). In their ZPD, learners work collaboratively until they are ready to do it independently (Haufather, 1996; Scott & Palincsar, 2013; Steele, 2001). The teacher can lead the learners through their ZPD and give guidance and information to continue their path to learning (Steele, 2001). The ZPD represents possible learning when a student is surrounded by appropriate instructional conditions (Haufather, 1996). Through the collaborative PD sessions, teachers will discuss and reflect on their students’ ZPD in terms of discourse use and how they can support student growth in the use of discourse.

**Sociocultural Theory in Professional Development Design**

Sociocultural views on learning show that learning and development depend on the context in which they are taught (Osana et al., 2011). For this reason, the PD in this research was learner-centered. Teachers took ownership of their learning, connecting it to their classrooms and reflecting on their practice (McGee et al., 2013). As part of the PD plan, participants collaborated on their implementation of discourse and reflected on how it impacted student learning.

Sociocultural theory was used to design the collaborative PD component of the study. While Vygotsky mainly focused on children, sociocultural theory can also be applied to adult learning (Burner & Svendsen, 2020). It is not an adult that needs to lead a child, but rather any learning situation in which at least one member cannot succeed alone (Haufather, 1996). A CoP allows teachers to
collaborate to improve their teaching practices (Olanoff et al., 2021). When engaged in CoP professional development sessions, teachers depended on and supported each other in the learning process (John-Steiner & Mann, 1996; Olanoff et al., 2021; Pyrko, 2017). Sociocultural theory stresses the importance of including collaborative, active, and authentic learning experiences in adult learning (Millis et al., 1994). Teachers need the opportunity to engage in CoP experiences where they share their ideas and thinking to develop new mathematical understandings and enrich their teaching pedagogy (John-Steiner & Mann, 1996). Sociocultural theory guided PD development to support participants in improving their teaching practices. Commognition will be used to guide the interactions within the CoP and develop a discursive understanding.

**Commognition**

Anna Sfard (2007) developed the commognition theory combining communication and cognition to create mathematical learning. Building on the sociocultural idea that thought and communication are linked in learning (Vygotsky, 1987), commognition focuses on individual discourse and how it changes to create mathematical understandings (Nachlieli & Heyd-Metzuyanim, 2022; Sfard, 2012). The commognition framework emphasizes thinking as discursive, and we must communicate with ourselves and others to develop and extend our mathematical learning (Ho et al., 2019; Sfard, 2020). As this individual discourse changes, so does our mathematical understanding (Nachlieli & Heyd-Metzuyanim, 2022; Sfard, 2020). To develop this mathematical discourse, learners need an experienced leader to modify, extend, and adapt their discourse
to include new ideas, processes, and information (Ho et al., 2019; Sfard, 2007). The teacher must be this leader to support, guide, and facilitate discourse as students become a member of the mathematical community (Sfard, 2012).

Mathematical discourse is a unique form of discourse that relies on several interrelated features (Sfard, 2007). Mathematical discourse encompasses four key components: (a) mathematical words and understanding, (b) visual mediators, (c) narratives, and (d) routines and patterns (Sfard, 2007). Learning and understanding mathematical words are vital for participation in mathematical discourse (Ho et al., 2019; Sfard, 2007). Visual mediators, such as graphs, diagrams, or number lines, allow participants to visualize and understand abstract concepts and see how numbers relate to each other (Ho et al., 2019; Sfard, 2007; Shinno & Fujita, 2021). A key component of discourse is using narratives that define and describe objects and relationships (Nachlieli & Heyd-Metzuyanim, 2022; Sfard, 2007). Narratives, like proofs, definitions, and theories, give a structure and explanation for mathematical thinking (Ho et al., 2019; Sfard, 2007). Finally, routines and patterns are vital to mathematical discourse (Shinno & Fujita, 2021). Finding and understanding the patterns within mathematics allows learners to connect mathematical concepts and expand their current thinking to new situations (Ho et al., 2019; Sfard, 2007). These forms of discourse require an adult mediator to guide and assist students as they learn to share their narratives and learn from others (Presmeg, 2016).

There are two main types of discourse in the commognitive framework: object-level and meta-level (Jeannotte & Kieran, 2017; Ho et al., 2019; Sfard,
Object-level discourse allows students to extend their current mathematical thinking. (Jeannotte & Kieran, 2017; Sfard, 2007). In object-level discourse, students extend their mathematical thinking to new ideas. For example, a student applies skip counting by 2s when they already know how to skip count by 5s. It is just extending the idea of number patterns to a new number. Meta-level discourse creates a new layer, such as learning about fractions when all that is known is whole numbers (Jeannotte & Kieran, 2017; Sfard, 2007). Meta-level discourse changes how students communicate mathematically (Jeannotte & Kieran, 2017; Sfard, 2007). This change is called “commognitive conflict.” This conflict is based on the idea that learning, as a change in discourse, is developed through changes in our communication (Ho et al., 2019; Sfard, 2007). This change in discourse allows the learner to see new possibilities, expand their thinking and deepen their understanding (Felton & Nathan, 2009; Nachlieli & Heyd-Metzuyanim, 2022). Teachers must develop guidance strategies to help students through their commognitive conflict (Nachlieli & Heyd-Metzuyanim, 2022; Sfard, 2007). Through the commognitive lens, learning mathematics is defined as individualizing mathematical discourse (Heyd-Metzuyanim & Sfard, 2012). In other words, it is the process of being able to have mathematical communication not only with others but also with oneself (Sfard, 2007). Therefore, if mathematical learning is a discourse, and teachers must guide it, they must gain a new understanding and gather the skills necessary to help students develop their mathematical understanding (Nachlieli & Heyd-Metzuyanim, 2022; Sfard, 2007). This research study used
commmognitive theory to educate teachers on how students use discourse to develop their mathematical understandings and analyze the discourse students use in the classroom (Ho et al., 2019; Nachlieli & Heyd-Metzuyanim, 2022). Students’ mathematical learning comes from opportunities teachers give them (Sfard, 2007). Using a commognitive lens, teachers can better understand how to support student development of mathematical discourse and why it is important (Ho et al., 2019; Sfard, 2012).

**Theoretical Connections**

Commognition and Sociocultural theory both see the connections between communication and thinking and stress the importance of social interactions in learning (Ho et al., 2019; Sfard, 2012). These theories value a teacher-leader who will guide students and their learning (Sfard, 2007; Vygotsky, 1987). This teacher guidance allows students the support needed to develop and extend their individual discourse and, thereby, their mathematical understanding (Ho et al., 2019; Nachlieli & Heyd-Metzuyanim, 2022).

Teachers and students engaged in mathematical learning through collaborative discourse throughout the study. Sociocultural theory guided the CoP aspect of the research study, as collaboration is vital to teacher growth (Jansen et al., 2017; Scott & Palincsar, 2013). Teachers worked with peers to plan, implement, and reflect upon their teaching practices. Sociocultural theory helped teachers guide their implementation of discourse in their classrooms. Teachers must build a discourse community within their classroom so students will be comfortable taking risks and sharing their mathematical thinking (Hufferd-
Ackles et al., 2004; Kutaka et al., 2018). Commognition guided the discourse portion of the research. Teachers and students needed to learn how to communicate their mathematical thinking and use it to develop their mathematical understanding (Sfard, 2007). As teachers learned about discourse-based teaching strategies and routines through PD, it influenced their practices and students' ability to communicate and develop their mathematical understanding. Together commognition and sociocultural theory will guide the PD's decisions, direction, and data analysis and interpretation.

**Purpose Statement**

The purpose of this study was to explore the influence of contextualized professional development on the use of discourse in the elementary classroom. Mathematical discourse is not just conversations during mathematics lessons; it includes reasoning, explaining, thinking, and sharing problem-solving strategies (Chapko & Buchko, 2004; Smith & Stein, 2018). The teacher controls the topic and the discourse's direction (Munson, 2019). Teachers need multiple strategies to question and guide students for productive discourse (Murata et al., 2017; Smith & Stein, 2018). Most teachers, however, did not learn mathematics through a discourse approach (Smith & Stein, 2018). Due to this lack of exposure, teachers may, in turn, need help to implement it in their classrooms (Boaler, 2018; Jansen et al., 2017; Smith & Stein, 2018). Participating teachers learned about mathematical discourse and how to effectively support productive mathematical discourse in their classroom through teacher-researcher-led professional development. Using this new knowledge, teachers implemented
discourse in their classrooms using the Ready Mathematics curriculum (Curriculum Associates, 2020). The study collected data on the changes in teachers’ practices and students’ mathematical discourse opportunities during instruction.

**Rationale for Action Research**

At its core, action research is conducted to generate new knowledge and contribute to the knowledge base of educational research (Clark et al., 2020; Elliott, 1991). It is an irritative process initiated by teachers in response to an educational situation to understand better, evaluate, and then change or improve instructional practices (Bassey, 1998; Clark et al., 2020; Elliott, 1991; Efron & Ravid, 2019; Sáez & Gracia, 2022). While this process can be fluid and dynamic, action research starts with a problem explored for deeper understanding and the goal of making changes (Efron & Ravid, 2019; Sáez & Gracia, 2022). The basic steps are shown in Figure 1.1. Action research is a cycle of action, reflection, and theory building followed by more action and then reflection to improve practice (Khler, 2012; Sáez & Gracia, 2022). With educational action research, teachers have the opportunity for substantial and critical reflection, leading to deeper content learning, improved instruction, and student understanding (Clark et al., 2020; Herr & Anderson, 2015).
An action research approach was selected as this study aims to change mathematical instructional practice through ongoing, contextualized PD. The personal and cyclical nature of action research allowed me to work with other participants to create changes in my school through PD (Herr & Anderson, 2015). The new Ready Mathematics curriculum (Curriculum Associates, 2020) introduced discourse-based, conceptual mathematics. This research sought to understand the impact of a PD program on the implementation of this curriculum. As a teacher and colleague, I was motivated to support my peers as they changed their teaching practices. Following the cyclical nature of action research, I used data analysis and critical reflection to improve the two-phased PD plan, to impact instruction and student understanding (Clark et al., 2020; Herr & Anderson, 2015). This action research was meant to be an ongoing learning process in which this researcher learned, shared, and adapted PD with the
teaching collaborators who may benefit and change their teaching (Clark et al., 2020; Koshy, 2010).

**Positionality**

In action research, the role of the researcher is essential as there is a relationship between the researcher, the participants, and the setting (Herr & Anderson, 2015). As the researcher in this study, facets of this relationship can impact the data I gathered and how I interpreted and used the data (Clark et al., 2020). In this research study, I was an insider collaborating with other insiders (Herr & Anderson, 2015). I worked with other teachers in my school to improve our mathematical instruction. While I was a teacher-leader facilitating the PD, I was also an insider as I learned and implemented this new curriculum with the participants. I shared my experiences and worked to improve my practices alongside the participants. Teachers collaborated with me to share ideas and shape the direction of our PD and individual learning. As an insider, I must consider how my beliefs and biases impacted the development of PD and my research findings (Efron & Ravid, 2013). I had seen the impact of my instructional changes from discourse-based PD on my students’ mathematical understandings. While that passion motivated me to help others, I could not let it influence the results of this study. Using focus group and individual interviews, as well as member checking (Brit et al., 2016; Feldman et al., 2018) through the open sharing of data collected, my collaborators (participating teachers) in this research helped ensure my biases did not influence the interpretation of the results. Through open access to my data and reporting, participating teachers
confirmed the accuracy of the reported data and the analysis of their experiences.

**Research Design Methodology**

The focus of this study was to identify the impact of PD on teaching practices and beliefs regarding mathematical discourse and how it impacted the use of discourse in the classroom. A holistic, mixed-methods case study approach (see Figure 1.1) was selected for this study as it allows for an in-depth study of teaching practices in a classroom situation (Ridder, 2017; Schoch, 2020). A case study allows for a longitudinal look at changes over time and is adaptable, as changes can be made to pursue understanding, and unexpected results can be found (Creswell & Creswell, 2014; Schoch, 2020; Yin, 2018). The case in this study was two teachers who participated in a two-phased PD series to improve their mathematics teaching practices. A holistic approach to data analysis was selected as it combines the individual data to create a single, overall picture of the case (Creswell & Creswell, 2014). A case study approach met the goals of this study as it allowed for an in-depth understanding of how and why teaching practices changed and presented a model that can be applied to other PD situations (Ridder, 2017; Schoch, 2020).

This study used a mixed-methods case study as multiple data sources allowed the triangulation of qualitative and quantitative data collected across observation, interviews, and surveys (Creswell & Plano Clarke, 2018; Yin, 2018). Qualitative research is exploratory and focuses on societal problems in which the researcher gathers and analyzes data to find patterns and themes (Creswell &
Teaching and learning are social endeavors in which meaning is created through interactions with others (Griffin et al., 2013; Erath et al., 2021; Venkat & Askew, 2018). Quantitative research, on the other hand, tests theories and provides numerical data that can be analyzed (Creswell & Creswell, 2014). Both types of research are valid and give different views of the research setting (Creswell & Creswell, 2014). Both approaches provide different types of data, which, when combined, can more accurately describe the dynamic teaching process (Khler, 2012). Therefore, this study integrated the two methods into a mixed-methods case study. The integration occurred throughout the study in the research design, methodology, and result reporting (McCrudden & McTigue, 2019). A holistic, integrated approach (Tashakkori et al., 2020) was used as it allowed for the simultaneous integration of qualitative and quantitative data, leading to one explanation of the results (Tashakkori et al., 2020).

**Figure 1.2- Mixed Methods Case Study**
The quantitative data collected through teacher surveys and observations provided specific numbers to be analyzed for changes in teaching practices and student opportunities for discourse. In contrast, the qualitative data from classroom observations and interviews were used to identify themes and personal experiences beyond the numbers. It allowed for the inclusion of teachers’ voices, experiences, and perspectives in the research (McCrudden & McTigue, 2019; Tashakkori et al., 2020). The multiple and varying data sources allowed for a more robust understanding of the impact of PD (Creswell & Creswell, 2014; Tashakkori et al., 2020). The data helped evaluate the success of the PD program in changing teaching practices by identifying, explaining, and quantifying specific teaching practices used by teachers after the PD sessions.

Research Procedure

Overview

The two-phased contextualized professional development began in August before the 2021-22 school year started (See Appendix B). A discourse survey on teachers’ use of discourse with students, including their comfort in implementing the new mathematics curriculum, Ready Mathematics (Curriculum Associates LLC, 2020), was administered to all teachers at an elementary school in Anchorage, Alaska (see Appendix C). Data from this survey was used to guide the study design in two ways. The first way the data was utilized was as a baseline for comparison at the end of the research, and the second was to guide the researcher in developing contextualized PD. All interested teachers at the school were given the opportunity to participate in the PD as it is important to
give teachers access to improve their instruction (Svendsen, 2020). Eight out of twenty-two teachers at the school participated in the semester-long PD session. Three primary teachers from the PD group volunteered as participants in this study, but one had to drop out due to a family situation. For this reason, a case study of two teachers with complete data was created.

The Phase One PD sessions occurred twice a month throughout the first semester of the school year, from August – December 2021. There were eight two-hour PD sessions, with additional independent reading and implementation practice in the classroom between sessions (see Appendix D). The research study participants had additional opportunities or support through classroom observations and individual follow-up sessions. Individual sessions were used to reflect on the observed lessons and plan for future lessons. The PD’s primary goal was to enhance teachers’ professional knowledge and skills related to mathematical discourse so that they might, in turn, improve their students’ mathematical understanding (Guskey, 2003; Kennedy, 2016).

Following the formal PD sessions, ongoing, informal PD continued for both participating teachers. This informal PD centered around their individual needs and goals for mathematics teaching and included 1:1 debriefing of mathematics lessons, resource support, and lesson planning ideas. During this time, the researcher completed data analysis of the Phase 1 data collected. Data analysis showed that while both teachers’ practices changed, their use of discourse during instruction was minimal, and dialogic interactions were mostly monologic. Monologic discourse is when one person speaks and another listens.
(Reznitskaya & Glina, 2018). A majority of their lessons were teacher-directed, with the teacher in the front of the room presenting the lesson. Analysis of participant interviews indicated that both participants struggled to implement student-student discourse in their lessons. These findings showed the need for more formal PD and the creation of Phase Two.

Both teachers agreed to participate in Phase Two during the 2022-2023 academic year. Two other teachers requested to join our group. Through focus group interviews, it was determined that a CoP, with the researcher as a facilitator, would best meet the needs of all participants.

The Phase 2 sessions began in August 2022 and continued through February 2023. The CoP met for nine sessions throughout this period. PD sessions were flexible in time and theme (see Appendix E). Some sessions were completed after school, while others were part of teacher in-service day planning. Sessions focused on teachers’ needs to increase and improve the use of discourse in the classroom. Between sessions, teachers implemented discourse lessons and reflected on their teaching practices.

Participants

While eight teachers participated in the Phase One portion of the PD, not all were included as participants in the research. Three teachers elected not to be part of the research, one was a special education teacher who did not have a specific group of students to work with, and one was a foreign language teacher who just wanted to apply discourse to her teaching. The final three volunteered to participate in the study, but one removed herself from the study partway through
due to a family situation. The remaining two were primary (grades K-2) teachers new to using discourse in the classroom.

Donna (pseudonym) was a second-grade teacher who had just returned to teaching after a 7-year break. She was a white woman with a Bachelor’s degree in Education. She had six years of upper elementary teaching experience and five years of substitute teaching. Donna teaches in the Chinese immersion program, which means she has two groups of students each day. She teaches math, writing, and reading. Chloe (pseudonym) was a first-grade teacher in the neighborhood program, a typical elementary classroom for students from the neighborhood who has been teaching for ten years. She is a white woman with a Master’s degree in Education. Chloe teaches one group of students all day long. She teaches all subject areas to her students.

Both teachers indicated on the initial discourse survey that they were anxious about using the new Ready Mathematics curriculum. They were looking for support to help them learn how to implement the new curriculum. Both teachers actively participated in the 2021 PD sessions. Participants received additional informal support in the spring semester of 2022. Data analysis and informal conversations at the end of the 2022 school year suggested that both teachers needed continued support using discourse in their classrooms. While both teachers made notable changes in their teaching practices after the initial round of PD, student discourse was still a minor part of their instruction. Informal comments shared by both teachers indicated they were still uncomfortable with discourse-based teaching. Both participants stated that they felt there was a lot
more to learn. Both participants agreed to participate in additional PD the following year. Two additional teachers requested to join the PD group, and a Community of Practice (CoP) was created.

**Data Collection**

A holistic, mixed-methods case study collected data for the action research study through surveys, questionnaires, interviews, and classroom observations (Creswell & Creswell, 2014; Yin, 2018). Multiple forms of data were used to determine the impact of PD on teaching practices and student opportunities for discourse (See Appendix F). A researcher-adapted pre- and post-discourse questionnaire (see Appendix C) was used to determine participants' comfort and use of discourse in their mathematics instruction. The Standards-Based Teaching Practices survey (SBTP, Ross et al., 2003) was used to gather data on the self-identified mathematical teaching practices of the teacher participants. Participants completed the survey before the implementation of PD, at the end of Phase One, and again at the end of Phase Two. Classroom observations using the adapted Mathematics Classroom Observation Protocol (MCOP²), adapted from Gleason (2015) and Dialogic Interaction Tool (DIT, Reznitskaya & Glina, 2018), were utilized to gather data on the discourse enacted in the classroom. The MCOP² (Gleason, 2015) focused on teaching strategies and discourse interactions, while the DIT (Reznitskaya & Glina, 2018) focused on the quality of those interactions. It was essential to gather data on participants' implementation of discourse in their classrooms to understand the PD's impact. Observations collected data on participating
teachers' practices regarding discourse in the classroom and if students were given more opportunities to engage in productive mathematical discourse during instruction. This data was used for data collection and participant reflection and feedback.

Semi-structured participant interviews (See Appendix G) were conducted pre-and post-PD and post-observation Interviews allow for open-ended responses and enable the participants to explain and reflect on discourse in the classroom (Creswell & Creswell, 2014; Efron & Ravid, 2013; McGee et al., 2013). Teachers' choices are often related to their beliefs and identity as a teacher (Ernest, 1989; Lerman, 2009). Interviews allowed them to share their perspectives on mathematics education and the use of discourse in the classroom.

**Data Analysis**

Data analysis will be completed throughout the research study (See Appendix F). Some analysis was conducted during the study to support adapting the PD plan to meet the participants' needs. Following the cyclical nature of action research, data collected from the SBTP, classroom observation, and interviews were triangulated for formative analysis of the research plan and to adapt the PD to meet teacher needs. Holistic, inductive coding was used to find themes and patterns in teachers’ experiences—a three-cycle coding process following Williams & Moser's coding process. (2019). The first cycle used open coding to identify key words and chunks (Linneberg & Korsgaard, 2019; Williams & Moser, 2019). Pattern coding was used for the second coding cycle to refine
further and organize the data (Williams & Moser, 2019). Selective coding was used in the final cycle to find overall themes from the data (Williams & Moser, 2019). This coding allowed more prominent themes and patterns to emerge from the data. In the final analysis, data was again triangulated to determine if PD can improve mathematics teaching and learning and give a voice to teachers' and students' struggles when new teaching methodologies using discourse are required.

**Significance of the Study**

For mathematical reforms to succeed, teachers need PD to support changes in their knowledge and teaching practices (Svendsen, 2020). Helping teachers improve mathematics content and teaching knowledge is critical to creating better student learning opportunities (Darling-Hammond, 2017; Polly et al., 2015). Teachers are more apt to change their thinking and practice when they can learn about and discuss student thinking about mathematics and how it impacts their instruction (Murphy, 2015; Murata et al., 2012). This study adds to the research on the impact of contextualized, learner-centered professional development on the use of discourse in their classroom. It was used to inform the participating district and recommended changes in professional development practices.

**Summary of Findings**

This study sheds light on how ongoing, contextualized professional development supports teachers in changing their teaching practices. In this two-
phased exploratory case study, teachers participated in two rounds of PD focused on discourse-based teaching strategies. After the first phase, participants demonstrated changes in their practices, based on the MCOP² and teacher interviews, but needed more time and support to become proficient in discourse-based practices based on the DIT. A second round of PD, using a CoP, gave teachers the time, opportunities, and support to implement new practices. Discourse became a natural and normal part of participants' teaching, providing students the opportunities for productive mathematical discourse. These findings suggest that PD must be contextualized around teachers' classrooms, where teachers can implement new practices and observe their impact on students' understanding.

**Dissertation Overview**

This dissertation is sectioned into five chapters focused on the influence of professional development on teachers' implementation of a discourse-based curriculum. Chapter one provides a summary of research questions, a rationale for the study, and a description of critical components of the research. Chapter two reviews the relevant literature on professional development and discourse and the two critical theories based on this dissertation: commognition and sociocultural theory.

Chapter three focuses on the methods used in the study. It details the tools used to collect data, the data collection process, and how the data was analyzed to determine the impact of professional development on teacher beliefs and instruction and student opportunities for discourse.
Chapter four describes the results of the study. It includes an analysis of the data collected throughout the study. Data collected through surveys and classroom observation was coded for patterns and trends in the impact of professional development on teaching practices participants use in their classrooms to elicit productive discourse. Classroom observation data shows students' mathematical discourse and understanding changes.

Chapter Five analyzes the data and adds to what is known about the impact of professional development and the use of discourse in the elementary classroom. Through data analysis, patterns, similarities, and relationships between professional development and the mathematical discourse in the classroom were discussed. It illuminates how professional development influenced mathematical discourse and how that, in turn, influenced student opportunities for discourse. The outcomes provided insight into the importance of effective professional development and how it can impact student mathematical understanding. It also determined the next steps needed to improve our mathematical instruction.

**Definition of Key Terms**

**Action Research:** A disciplined process of inquiry conducted by and for those taking action. The primary reason for engaging in action research is to assist the participants in improving and refining their efforts (Herr & Anderson, 2015).

**Commognition:** A theory grounded in the assumption that thinking is a form of communication and that learning mathematics is tantamount to modifying and extending one's discourse (Sfard, 2007).
**Community of Practice (CoP):** A group of people who share a common concern for something and work together to learn how to do it better (Wegner-Trayner & Wegner-Trayner, 2015).

**Case Study:** a research design where the researcher completes an in-depth exploration of an event, process, or individual (Creswell & Creswell, 2014).

**Conceptual Knowledge:** An integrated approach to mathematical learning focusing on mathematical ideas and their connections. It organizes ideas into a coherent whole instead of memorizing procedures or facts (Kilpatrick et al., 2001).

**Contextualized Learning:** Learning embedded into a teacher's classroom with their students. (Darling-Hammond et al., 2017)

**Holistic Case Study:** A holistic case study focuses on a single unit of analysis. (Yin, 2018)

**Mixed-Methods Design:** A procedure for collecting qualitative and quantitative research methods to understand a research problem. (Tashakkori et al, 2020).

**Pedagogical Content Knowledge (PCK):** The knowledge of combining content and how to teach and adapt the content to meet the needs of diverse students (Shulman, 1986).

**Procedural Knowledge:** Mathematical learning focuses on understanding the steps and procedures needed to complete a task (Kilpatrick et al., 2001).

**Productive Discourse:** classroom communication in which the participants pay close attention to what others are saying and understand the perspective of
others, and respond to these differences by providing evidence of their own
(Smith & Stein, 2018).

**Ongoing Professional Development:** Formal or informal learning opportunities
for teachers to grow and develop that extend over time (Desimone, 2009).

**Sociocultural Theory:** A theory based on learning as a socially mediated
process in which children acquire their cultural values, beliefs, and problem-
solving strategies through collaborative dialogues with more knowledgeable
members of society (Vygotsky, 1978).

**Standards of Mathematical Practice (SMP):** The knowledge and expertise that
mathematics educators should seek to develop in their students. They are the
processes and proficiencies students need to succeed in mathematics education,
such as problem-solving, reasoning, explaining, and making connections (See
Appendix A) (CCSS, 2010).

**Traditional Mathematical Teaching Practice:** The teaching method is when the
teacher presents a concept to the class, shares the procedure for solving it, and
then has the students practice using it (Chapko & Buchko, 2004).
Chapter 2: Literature Review

A call for mathematics reform has echoed nationwide, yet mathematics scores have remained unchanged over the past ten years (NAEP, 2019). In the 1990s, the Common Core State Standards were created to shift educational practices from the procedural memorization of facts to the conceptual understanding of mathematical concepts (CCSSO, 2010). The CCSS movement called for educators to transform existing instructional practices, shifting focus to developing conceptual understanding and focusing less on procedural competency (NCTM, 2000). Students with conceptual understanding know more than facts or procedures; they understand why an idea is essential and in which context it would be useful (Kilpatrick et al., 2001). This shift in focus intensified demands on teachers to change what they teach and how they will teach it (Cosner et al., 2020; Jansen et al., 2017; Perry et al., 2015). The Standards of Mathematical Practice (SMP) (CCSSO, 2011) specifically recommend that teachers support students in learning how to construct viable arguments, critique the reasoning of others, attend to precision while communicating, and reason quantitatively while solving and discussing mathematical tasks. To do this, teachers must know more than just the rule to follow or answer to find; they need to understand the mathematical concepts behind the problem and be able to explain and support students in understanding the concept (Boaler, 2018;
Lampert, 1990). Most teachers, however, enter the profession without the mathematical content knowledge or effective pedagogy required to teach discourse-based, conceptual mathematics (NCTM, 2014; Murata et al., 2012). Most teachers learned mathematics by memorizing procedures and skills and now need assistance understanding mathematics' conceptual, interrelated nature (Boaler, 2018; Jansen et al., 2017).

**Statement of Problem**

The adoption of CCSS-M (CCSSO, 2010) cannot raise students’ mathematical achievement alone—they depend on districts, schools, and teachers to understand and interpret the standards and effectively shift instructional practice (Allensworth et al., 2021; Killpatrick et al., 2001). Most teachers in the US have not received adequate PD focused on CCSS-M and discourse-based approaches to mathematics (Boaler, 2018; Linder, 2011). Teachers are uncomfortable and unprepared to teach conceptual mathematical content to their students (Greenberg & Walsh, 2008; Gomez Zwiep & Benken, 2013). Helping teachers to improve their mathematical pedagogy to include higher-level thinking and mathematical discourse in the classroom is critical to creating better student learning opportunities (Darling-Hammond, 2017). Teacher learning through PD is vital to successful implementation (Sztajn et al., 2012), yet in most cases, PD is not offered or is ineffective (Cosner et al., 2020; Linder, 2011; Perry et al., 2015). Teachers need ongoing, learner-centered PD to help them refine their teaching and beliefs about learning mathematics (Anderson et al., 2018; Cosner et al., 2020; Guskey, 2003).
Conceptual mathematical learning is comprehending mathematical concepts and operations and their relationship (NRC, 2001). It is often characterized by the connections between mathematical procedures and their ideas (Hiebert & Carpenter, 1992). With the adoption of CCSS-M (CCSSO, 2010), teaching mathematics was no longer the practice of a teacher-prescribed procedure but rather the understanding of mathematics concepts (Jansen et al., 2017; Polly et al., 2014). The SMPs, a part of the CCSS-M, are the foundation for mathematical thinking and processing (Kilpatrick et al., 2001). Even though research demonstrated the need for change in mathematical teaching pedagogy with the adoption of CCSS-M, many elementary teachers in the United States did not receive adequate PD focused on these new approaches to mathematics (e.g., Linder, 2011; Polly et al., 2015; Beswick, 2005). For this reason, teachers are uncomfortable and unprepared to teach conceptual mathematics to their students (Greenberg & Walsh, 2008; Zwiep & Benkin, 2012). Teaching mathematics for conceptual understanding requires understanding the tasks of teaching – posing questions, explaining, choosing representations, analyzing errors, mediating discussion, and using accurate language (Thames & Ball, 2010). This kind of teaching requires different pedagogical knowledge that most teachers do not naturally have (Kutara et al., 2018; Murata et al., 2012). Ongoing, conceptual, and active learning professional development is vital if teachers are to be successful mathematics educators (Darling-Hammond, 2017; Polly et al., 2015).
Successfully implementing mathematics education reform requires that teachers change traditional, procedural-based teaching practices significantly and develop a discourse community in their classrooms (Brown & Hirst, 2007; Lampert, 1990; Murata et al., 2017; NCTM, 2000). A discourse community allows students to share their ideas, defend their thinking, and prove their understanding to each other (Hufferd-Ackles et al., 2004; Murata et al., 2017). Through discourse, mathematics becomes a conceptual process of engagement instead of a procedural set of rules to memorize (Murata et al., 2012). It is a way to engage in mathematical practices such as reasoning, evaluating arguments, and explaining patterns (Murata et al., 2017). Students can use discourse to share their understandings, justify their ideas, and explain their thinking (Brown & Hirst, 2007; Lee & Walkowiak, 2015). For students to engage in productive discourse, they must feel comfortable and supported in their efforts (Lee & Walkowiak, 2015; Mercer & Sams, 2008) and be allowed to engage in conversations with their peers (Kutaka et al., 2018; Murata et al., 2017). Teachers must learn varied instructional strategies that focus on mathematical relationships and engage students in mathematical discourse (Stigler & Hiebert, 2009). It is often a challenge for teachers to shift their teaching to move beyond teacher-directed discourse (Lampert & Blunk, 1998; Murphy, 2015; Murata et al., 2017). Professional development is needed to give teachers the skills, confidence, and understanding required to develop this essential discourse community (Lee & Walkowiak, 2015; Murata et al., 2017).
Significance of the Research Problem

The successful implementation of CCSS standards depends on the work of schools and teachers to interpret the standards and effectively shift instructional practices (Allensworth et al., 2021). Mathematics education reform demands that teachers change traditional teaching practices and develop a discourse community in their classrooms (NCTM, 2000). Professional Development is the path to that instructional change. (Allensworth et al., 2021; Desimone, 2009; Kennedy, 2016). The transition to reform mathematics teaching is a challenging task, and teachers often need clarification about what this kind of classroom would look like, let alone how to get there (Huffard-Ackles et al., 2004). Improving teacher quality is a complex task since many factors, including teachers’ content knowledge and perceptions, impact their instructional choices in the classroom (Gomez-Zweip & Benkin, 2013). Therefore, it is critical to understand what makes PD effective. (Desimone, 2009).

Developing a discourse community in the classroom is an essential step in mathematical reform, yet teachers often need help with implementation (Hufferd-Ackles et al., 2004). Discourse-based teaching is different from how most teachers learned mathematics, and they are uncomfortable with a different style of instruction (Gee & Whaley, 2016; Mapolelo & Akinsola, 2015). When teachers provide opportunities for students to engage in discourse and communicate their mathematical thinking, students demonstrate a deeper mathematical understanding (Polly et al., 2015). Productive discourse allows students to process information, share ideas, listen, respond to others, and collaborate in
problem-solving (Walter, 2018). Therefore, it is essential to determine how to support teachers in implementing a discourse-based approach in their classrooms (Ni et al., 2021). Strong and consistent information about which measures of knowledge matter most for high-quality teaching and student learning and the trajectories of improvement for teachers needs to be improved (Desimone et al., 2016). This research study aims to add to the literature regarding approaches to teacher PD, focusing on the impact of ongoing, learner-centered teacher PD on participants' teaching practices and use of discourse.

**Themes of Literature Review**

The key themes of this literature review are (1) teachers’ impact on students’ mathematical learning, (2) the result of effective professional development in teacher instruction, (4) the importance of contextualized learning in professional development, (5) the need for ongoing professional development, (6) communities of practice in professional development, and (7) the impact of mathematical discourse on elementary mathematics instruction.

**Teachers’ Impact on student mathematical learning**

Teachers are one of the critical factors in mathematics education (Lave & Wenger, 1991; Mapolelo & Akinsola, 2015). The instructional practices teachers use during mathematics instruction have the potential to impact student achievement (Firmender et al., 2014; Lee & Walkowiak, 2015). Effective teachers can cover more content at higher levels of mathematical understanding (Desimone et al., 2016). Students will demonstrate deeper mathematical understanding when their teachers present mathematically rich tasks, allowing
students to explore concepts, connect mathematical ideas, and communicate their mathematical thinking (e.g., Gomez Zweip & Beknen, 2013; Walter, 2018; Webb et al., 2021). In discourse-based teaching, the teacher must be a facilitator to support the development of students' discourse skills (Firmender et al., 2014). Educational research must consider the teacher's impact in any classroom (Darling-Hammond, 2017; Desimone, 2009).

Webb et al. (2017) looked at the teacher practices that promote discourse in the classroom. Teachers play an essential role in facilitating student collaboration and can do many things to support students’ use of discourse (Mercer & Sams, 2008). Through their research, Webb et al. (2017) shared different strategies teachers must use to prepare their students for collaboration:

- Set the norms and routines for discourse.
- Scaffold instruction to teach students how to carry out discourse strategies and help them think critically.
- Model these discourse strategies with students so they, in turn, can practice the skills in their collaborative groups.
- Use probing questions to increase student thinking and uncover details of their problem-solving strategies.
- Support students in explaining their ideas.

Researchers Webb et al. (2017) also analyzed teachers' different classroom participation structures and the discourse strategies used in each. Participation structures are how teachers organize students, ranging from whole-group discussions to small-group work and collaborative problem-solving. Data
collected showed that each of these structures could support student participation. Future research needs to be conducted to determine what teacher practices increase student participation in each structure and how to assist teachers in their implementation (Webb et al., 2017).

Firmender et al. (2014) examined the relationship between teachers’ discourse instructional practices and student achievement in the primary classroom. This study focused on teacher practices in implementing two SMPs (CCSSO, 2010), constructing viable arguments and critiquing the reasoning of others, and attending to precision. Specifically looking at the changes in mathematical vocabulary, Firmender et al. (2014) studied how using the SMPs impacted student achievement. Thirty-six kindergarten and first-grade teachers and 601 students participated in this study. Quantitative data was collected through teacher observation and standardized mathematics tests. Observational data focused on teacher use of the SMP strategies in the classroom. Standardized test scores were used to determine a change in mathematical achievement. Results indicated a significant relationship between using the SMP teaching practices and increasing student achievement. Teachers’ use of CCSS-M practices can positively impact student achievement (Firmender et al., 2014). More research, however, is needed to investigate the effectiveness of SMP-based teaching strategies in classrooms.

In a quantitative research study, Lee and Wilkowiak (2015) examined the teaching practices of 74 second-year teachers, focusing on the learning opportunities they presented to their students. Results indicated that most
participants used methods that followed their beliefs about mathematics teaching and learning. Data was gathered on discourse present in each lesson, explicitly using a mathematical discourse community and opportunities for students to explain and justify their thinking. Analysis showed that teachers with more mathematical knowledge for teaching (MKT) and a belief that mathematics is an interactive discipline used more discoursed-based strategies, giving students more opportunities to explain and justify their thinking. This research demonstrated the need for additional research on teacher beliefs and effective ways to change them.

**The Impact of Professional Development on Teaching Reform**

Continued professional development (PD) and teacher learning are critical facets of educational reform in the US (Desimone, 2009; Osana et al., 2011). Many reforms depend on teacher learning and improved instruction to increase student learning (Gellert, 2012; Sykes, 1996). Despite these efforts, there is a wide range of what can be called PD and limited concrete data on what makes it effective (Gee & Whaley, 2016). However, some trends have been found that can guide PD to improve teacher learning and understanding. PD should:

- Incorporate active learning: Teacher learning should be the same type of learning their students will use (Darling-Hammond et al., 2017).
- Support collaboration with learning communities (McGee et al., 2013).
- Provide opportunities for discourse (Ni et al., 2021).
• Provide ongoing coaching and support: Most change occurs after implementation in the classroom, and there is evidence of improved learning when continuing follow-up occurs (Guskey, 2003).
• Use models of effective practice: Helping teachers develop pedagogical knowledge is valued more when observed and implemented (Murata et al., 2012).
• Offer opportunities for feedback and reflection: Specific procedures are needed to provide feedback on results (Guskey, 2003).
• Be sustained: Learning activities should be spread over a semester or about 20 hours of total contact time (Desimone, 2009).

However, PD design features may need more reliable success predictors and more research (Kennedy, 2015). What is known is that teachers are more likely to change their thinking and teaching when they are provided opportunities to learn about their instructional practices and student thinking and have the chance to discuss their mathematics instruction (Carpenter et al., 1989; Murata et al., 2012). To increase the likelihood of success in PD regarding teacher change and student learning, learning must be grounded in the daily lives of teachers to address their needs to improve classroom teaching (Kennedy, 2015; Singer et al., 2011).

The Primarily Math Elementary Mathematics Specialist Program (PM) was the focus of research by Kutaka et al. (2016). This in-depth program required 18 credit hours spread over 13 months. The courses focused on MCK, teaching pedagogy, and child development, emphasizing student thinking and how to
implement new teaching practices. Teachers volunteered and were selected for the program based on a multi-part application. Throughout the PM program, teachers worked in cohort groups supporting and learning from each other. The longitudinal research study completed by Kutaka et al. (2016) followed several cohorts of participants over five years. Data analysis showed that PM was successful in changing teacher beliefs and practices. Teachers increased their student-centered teaching beliefs, mathematical content knowledge, and confidence in teaching mathematics. Participants shared that the opportunity to learn and practice challenging mathematical content and collaboration with peers were key factors in program effectiveness (Kutaka et al., 2016).

Collaboration was a key factor for Murata et al. (2012) in their yearlong study investigating the paths of three individual teachers as they learned and introduced discourse into their classrooms. A lesson study method of professional development was used, which assists teachers in moving to a more student-centered approach. In a lesson study, the PD instructor provides a routine for teachers to extend their knowledge for teaching through a cycle of setting goals, analyzing the curriculum, planning lessons, teaching the lesson, and then reflecting in a collaborative setting. Each teacher took a different growth path in this study. The backgrounds and knowledge of each participant impacted their decisions and the use of classroom discourse. The collaboration meetings shared these differences, allowing teachers to gain new teaching ideas and take risks in their discourse implementation. This study reinforced that learning is a
social endeavor, and teachers can learn together as they progress in their professional development (Murata et al., 2012).

Supporting teachers’ mathematical instruction through PD is the focus of the Polly et al. (2017) study. Fifteen kindergarten teachers participated in an intensive 80-hour PD, 48 hours in the summer, and 32 hours of follow-up and in-classroom support. The PD was evaluated to determine teacher content knowledge, beliefs, and instructional practices. Data collected showed a minimal increase in teachers’ content knowledge, but this could be attributed to the fact that the content taught differed from what kindergarten teachers typically teach (fractions and algebra). Teachers’ beliefs slightly changed, but many teachers self-reported having discovery/connectionist beliefs before the study. Discovery/connectionist beliefs center around the idea that students discover and create their learning. The teacher implementation and student achievement showed the most significant results. The number of teachers using student-centered instructional approaches went from 8 teachers to 14. This data suggests two things; first, teachers who believed they were discovery/connectionists did not teach in this manner. Secondly, teacher implementation changes are precursors to changes in teaching beliefs. This study supports the theory that teachers must observe how teaching practices impact student understanding before changing their beliefs (Polly et al., 2017).

High-quality PD is central to improving education as it can change teachers’ practices (Guskey, 2003; Webb et al., 2017). Research shows that developing effective teacher PD can increase the quality of mathematics
education (Desimone, 2009; Polly et al., 2017). The challenge is determining what makes effective PD that changes classroom mathematics instruction (Desimone, 2009; Kennedy, 2016).

**Contextualized Professional Development**

When developing teacher PD, learning needs to be contextualized around the classroom where teachers will implement this new learning (Darling-Hammond, 2017; Lave & Wegner, 1991). Traditional PD often occurs from lectures, books, and generally out of context to the classroom (Lave & Wegner, 1991). This does not allow teachers to connect the new learning to their teaching. Authentic learning, however, occurs through relationships between peers and connecting knowledge with contextual understanding in the classroom (Lave & Wegner, 1991). Therefore, to be effective, it is essential to embed learning into the ongoing experiences of learners and create opportunities to transfer learning to the classroom (Darling-Hammond, 2017; Kennedy, 2016).

Singer, Lotter, Feller, and Gates (2011) explored a model of situated PD with middle school science teachers. While the subject was science, the goal was similar to the study in this dissertation as it explored change in teachers’ practice as it aligns with teaching pedagogy. Professional Development focused on allowing teachers to implement new teaching practices with their students and opportunities for critical reflection. The thirteen teachers included in the study participated in an extended summer institute with follow-up support during the school year. Quantitative results significantly impacted teaching practices, with teachers using inquiry practices they had not used before the PD. Qualitative
results showed that working collaboratively with peers and the ability to practice lessons in their classroom had a positive effect on their teaching practices. The study concluded that the situated nature of the PD was an integral part of the PD’s success (Singer et al., 2011).

Teacher quality is directly associated with student achievement and learning (Hill et al., 2005; Polly et al., 2017). Reform-based teachers should pose challenging questions, assess student understanding, and create authentic mathematical tasks (NCTM, 2012). However, most teachers do not have the skills or knowledge to teach this way (NCTM, 2014). Researchers Polly et al. (2015) worked with almost 300 teachers in three different 2-year cohorts to determine the impact of sustained, learner-centered professional development. After two years of PD, researchers found that while the gains were less significant than expected, many teachers did transition to a more student-centered teaching approach which, in turn, led to higher student achievement. Polly et al. (2015) concluded that learner-centered PD based only on student-centered teaching has a positive impact, but extensive and ongoing PD is needed for significant change.

Ongoing professional learning communities were the PD approach for research conducted but Gee and Whaley (2015). Sixteen teachers were selected to participate in this 2-year PD case study. Teachers attended a summer institute focused on increasing their mathematical knowledge and understanding each summer. Teachers collaborated on creating a mathematical unit, including a problem-solving lesson. During the school year, teachers taught problem-solving
lessons, observed each other, and collaboratively reflected on the teaching practices used. Qualitative data were collected through observations, interviews, and reflection journals. Results showed a significant change in teaching practices throughout the two-year study. Teachers understood problem-based learning and the need for increased student conceptual understanding. Many, however, could not define the change in their students’ understanding, only that it was different. More discussion is needed on supporting teachers through professional development (Gee & Whaley, 2015).

Understanding what makes professional development effective is vital to mathematics education reform (Desimone, 2009). To be effective, it must address teachers’ content knowledge and perceptions about the content and be tied to their teaching and learning situations (Gee & Whaley, 2016; Osana et al., 2011; Polly et al., 2015;). Teacher learning and change are more effective when the PD is connected to teachers' classrooms (Osana et al., 2011; Ni et al., 2017). The contextualized PD strategy allows teachers to be more actively involved in their learning and see the direct impact of the PD on their students (Desimone, 2009; Schifter, 1998). Professional development cannot just focus on changing teacher beliefs; teachers need to experience and practice implementing instructional practices while developing content their knowledge (Jansen et al., 2017) through content-specific learning experiences which challenge their thinking and allows them to reflect on their practice (Zwiep Gomez & Benkin, 2012). Often the best learning can happen when it is connected to the teacher’s
classroom (Desimone, 2009), and the content knowledge is directly related to the student's mathematical learning (Kutaka et al., 2018).

**Community of Practice (CoP) in Professional Development**

A Community of Practice is a collaborative learning process by a group about a shared concern or problem (Azukas, 2019; Olanoff et al., 2021; Wenger-Trayner & Wenger-Trayner, 2015). Members work together to share information and learn from each other (Voskoglou, 2019; Wenger-Trayner & Wenger-Trayner, 2015). There is an opportunity to exchange ideas, share experiences, and solve problems (Voskoglou, 2019). A CoP shifts PD to a collective learning approach where all members’ practices change through the actions and learning of all group members. (Buysse et al., 2003; Olanoff et al, 2021). Learning becomes a social process where the goal is the group's growth instead of individual success (Pykro et al., 2017). Researchers Olanoff, Masingila, and Kimani (2021) researched a CoP created to support Mathematics Teacher Educators (MTE) as they developed the necessary skills to teach preservice elementary teachers. Three MTEs, two novices, and one expert participated in the yearlong study. All participants believed the CoP would be beneficial to improving their teaching practices. Throughout the study, teachers developed their mathematical content knowledge and ability to teach others. Participants observed each other and engaged in group support and reflection. Findings showed growth in four areas; (1) elementary mathematics content knowledge, (2) understanding of how students learn math, (3) ways to facilitate problem-solving, and (4) a better understanding of their role as MTE. Researchers concluded that
the time spent in group reflection allowed them to receive feedback and gain new perspectives on teaching that would not have been available if they had worked independently (Olanoff et al., 2021).

In a 2012 research study, Gellert focused on using CoP and how reflective practice impacts teaching. In Gellert’s (2012) study, three teachers videotaped their teaching and met to discuss and reflect on the teaching practices. After several observations and group discussions, Gellert noticed a significant change in the level of the teacher’s comments and observations, being more critical and analytical instead of superficial. Teachers gained confidence in their mathematics teaching ability and ability to assist students with misconceptions as they gained a deeper understanding of the core content. Gellert (2012) stated that collaboration supported teachers as they changed their classrooms.

A case study involving the National Health Service in Scotland showed that providing resources to a group and allowing access to shared experiences and opportunities for discussion does not mean a CoP has been created (Pykro et al., 2017). Researchers in this study followed a leadership team as they tried to create a CoP of healthcare workers to improve their understanding of dementia. While there was an increased understanding of dementia, there was little interaction between group members, and no collective understanding was built. Researchers concluded that because leaders focused on sharing information instead of connecting people with the problem and each other, there was no reason for mutual engagement and collaboration (Pykro et al., 2017).
The effectiveness of a CoP in improving K-12 teachers’ self-efficacy in teaching personalized learning was the focus of a study by Azukas (2019). Eighteen teachers volunteered to participate in the PD program. Teachers engaged in a blended CoP over a nine-month school year. Using pre- and post-efficacy surveys and qualitative interview data, findings showed increased confidence in planning for personalized learning, sharing their knowledge, knowledge of students, and problem-solving skills. The idea that they were “all learning together” was a common theme among participants as the critical factor in the program's success (Azukas, 2019, p.299).

Communities of Practice are groups of people who share concerns, want to improve their practice, and work together to make a change (Voskoglou, 2019; Wenger-Trayner & Wenger-Trayner, 2015). Not all groups of learners are CoPs. Wenger (1998) detailed three key characteristics that define a successful CoP:

- **Domain**: An area of interest that identifies members from others.
- **Community**: Members engage in joint activities and discussions, support each other, and share information.
- **Practice**: Members develop shared experiences, tools, and practices to address problems (Voskoglou, 2019).

Participants in a CoP are not just part of a group but members of a learning community working together for the betterment of all (Azukas, 2019; Voskoglou, 2019; Wenger-Trayner & Wenger-Trayner, 2015).
The Impact of Discourse on Mathematical Understanding

The Standards for Mathematical Practice (SMP) in the Common Core Mathematics Standards (CSSO, 2010) recommends that teachers provide opportunities for students to construct viable arguments, critique the reasoning of others, attend to precision while communicating, and reason quantitatively while solving and discussing mathematical tasks. Mathematics learning is a social experience where deeper learning can be achieved through discourse in the classroom community (Griffin et al., 2013; Smith & Stein, 2011). Discourse assists students in understanding key ideas, deepening their mathematical understanding, and removing misconceptions (Baxter et al., 2002; Smith & Stein, 2011). Discourse, also called exploratory talk (Mercer & Sams, 2008; Murphy, 2015), classroom talk (Brown & Hirst, 2007), or math talk (Hufferd-Ackles et al., 2004), is the communication in a classroom that makes learning and thinking visible (NCTM, 2014). Discourse is essential in creating student engagement and developing mathematical understandings (Brown & Hirst, 2007; Mercer & Sams, 2008). Significant research has been conducted on the impact of discourse on mathematical thinking, effective ways to create a discourse community in the classroom, and how to assist teachers in creating and maintaining that community (Murata et al., 2017; Polly et al., 2015; Murphy, 2015).

Teaching through discourse is a teaching approach that includes students in the collaborative construction of meaning and learning (Mercer & Sams, 2008). Teachers and students must share control over the critical aspects of classroom
discourse (Reznitskaya & Gregory; M., 2013). This transition to a new kind of teaching challenges teachers (Huffard-Ackles et al., 2004).

Gathering data on an elementary teacher’s attempts to engage all students in discourse, Baxter et al. (2002) researched the evolution of classroom discourse from teacher-centered to student-centered in a 4th-grade classroom. Teacher-centered discourse is when the teacher leads the discourse, and most responses are between the teachers and individual students. Student-centered is when the students are engaged in discourse amongst themselves, with the teacher as a guide and facilitator (Baxter et al., 2002). Significant scaffolding was needed as the teacher introduced discourse routines in the classroom. Some students needed additional support, such as mini-lessons, sentence stems, and visual representations, to successfully engage in classroom discourse (Woodward & Montague, 2002). It was determined that while all students could participate, their differences created teacher challenges in maintaining high expectations while meeting students’ needs. Knowing productive discourse is essential, and encouraging teachers to use it is not enough. Ongoing PD can support teachers in their implementation of discourse. It was concluded that teachers need support to balance who, when, and how they create discourse in their classroom (Baxter et al., 2002).

Martin et al. (2015) researched the impact of discourse-based professional development on the questions teachers posed to build student understanding. Forty-eight elementary teachers participated in a year-long professional development model, Content Development for Investigations (CoDE-I). Data was
collected through teacher observations focusing on the relationship between teachers’ use of high-level questions and the tasks students completed. Teachers were not always successful in their attempts to create a discourse community. Martin et al. (2015) found that teachers tended to over-direct or do too much of the task when they were concerned it would be challenging. If students struggled to explain their answers, teachers would help them complete the task. These extra supports and decreased cognitive demands make the changes in students’ mathematical understanding insignificant. The teachers’ desire for the students to complete the task outweighed their need for students to engage in productive struggle and develop conceptual understanding. This study revealed that teachers need ongoing support and PD to support and scaffold students navigating this discourse-based teaching and learning (Martin et al., 2015).

The use of exploratory talk, another term for discourse, was the focus of research by Mercer & Sams (2008). This study gave two teachers detailed, discourse-based lesson plans to support their teaching and scaffold learning for their primary students. These lesson plans focused on developing student talk skills using mathematics content. Data was gathered to determine the impact of the lessons on students’ mathematical understanding. One teacher used exploratory talk with repeated reminders of discourse routines. Data from this classroom showed that students improved their language and mathematical reasoning skills in their discourse. The other teacher allowed time for student talk, but there was little structure or routine. This class struggled to listen to each
other and build their conceptual knowledge. Interviews with students emphasized results, as the students who participated in exploratory talk agreed that their mathematical thinking and cooperation ability were improved due to the lessons.

Elementary students can better show mathematical understanding when teachers ask for mathematical explanations and use probing questions (Jansen et al., 2017). Creating a classroom discourse, however, can be a challenge for many teachers (Michaels & O’Connor, 2015; Murphy, 2015). Research by Ni et al. (2021) studied the effect of PD on assisting teachers in developing their practices for engaging students in discourse. Thirty-two 4th-grade teachers were selected to participate in the program. They participated in 48 hours of PD over 4 ½ months, including workshops, classroom observations, and follow-up discussions. PD centered on how discourse can affect student learning, assisting teachers in understanding and enacting discourse instructional practices, facilitating teacher reflection on their use of discourse in their teaching, and assisting teachers in developing their repertoire of discourse moves. Participants included 32 teachers from 16 different schools. Using a quasi-experimental design, researchers collected data to determine if the intervention produced discourse teaching changes. Data collected on student discourse behaviors in the classroom. Results indicated that participants used more discourse with their students, with an increased tendency to prompt students and encourage them to engage with others’ ideas.

Discourse must be essential to mathematics instruction (Martin et al., 2015). Teachers need to develop instruction that centers around students’
mathematical thinking and create opportunities for them to develop mathematical understanding through discourse (Gellert, 2012; Mercer & Sams, 2008; Muson, 2019). Students’ mathematical thinking improves when teachers ask high-level, engaging questions (Baxter et al., 2002; Hufferd-Ackles et al., 2004). When students can describe and explain their thinking, they can recognize misunderstandings, internalize problem-solving strategies, and develop new understandings (Michaels & O’Connor, 2015; Murata et al., 2017). Questions must go beyond asking what a student has done to the reasons behind their mathematical decisions (Munson, 2019). For teachers to succeed in this endeavor, they must receive ongoing, contextualized professional development with continued support from a learning community (Griffin et al., 2013; Hufferd-Ackles et al., 2004; Murata et al., 2017).

Theoretical Framework

Sociocultural Theory

Sociocultural theory suggests that human learning is a social process and depends on the learning context (Mercer & Howe, 2012; Osana et al., 2011). It focuses on the idea that children learn social tools based on their culture that help them navigate their world (Steele, 2001). Based on research from Vygotsky (1978), it is believed that development occurs twice, first through social interaction and then at an individual level. His Zone of Proximal Development (ZPD) defines what a learner can do independently and what can be achieved with the support and guidance of a mediator (Burner & Svendsen, 2020; Mercer & Howe, 2012; Steele, 2001). Learning must be a social endeavor in the
Steele (2001) researched the use of communication to develop mathematical understanding. She used the observation of a 4th-grade teacher to see the impact of a sociocultural approach to teaching mathematics. Ten teachers were initially observed, but one individual teacher was selected as she showed the highest fidelity to the sociocultural approach. Two core aspects of the sociocultural theory were observed in her teaching. First, the teacher supported students through the ZPD as she guided and supported students with mathematical activities broken into phases that developed the skills and understandings students needed to assimilate prior knowledge into their new learning. Additionally, there was a focus on collaborative student conversations where the teacher facilitated productive discourse. In these conversations, students shared knowledge and developed mathematical understanding. The emphasis of her teaching was not on the teacher transmitting knowledge, but on students collectively creating meaning through discourse using the activities the teacher had organized. While these activities were planned, they were not scripted, so students could explore and make their connections. Data from the observations showed that a sociocultural approach created a learning context.
that allowed the teacher to support students in developing mathematical language and skills.

Steele, Mercer, and Howe (2012) wanted to research the impact of sociocultural theory; specifically Vygotsky’s idea that acquisition and language transform children’s thinking and learning is a collaborative exercise (Vygotsky, 1978) on mathematical teaching. They reviewed empirical research on sociocultural classroom talk and discussed its educational implications. They determined that teachers must use less “authoritative” talk and more dialog with and amongst students (Mortimer & Scott, 2003). Teachers must be aware of the function of talk and how it can best support student learning. They also focused on the importance of social interaction in mathematical learning. Their findings indicate that collaboration effectively develops student learning, and an adult moderator is vital to success. Students working together can lead to discourse, but usually not productive discourse (Mercer & Howe, 2012). Students need an adult to guide them and support their mathematical language development to progress their understanding. In conclusion, they determined that teachers need more PD to learn why discourse is important and how to facilitate it in the classroom.

Professional development is necessary for teachers to learn the methods needed to effectively create a sociocultural environment in the classroom (Mercer & Howe, 2012). Just as students need a supportive and discourse-based community for learning, so do teachers (Osana et al., 2011; Svendsen, 2020). Their mathematical PD must include classroom implementation so teachers can
connect their discourse learning to their teaching (Venkat et al., 2018). They also need repeated opportunities to discuss and practice the strategies with scaffolding to support their learning (Erath et al., 2021). A professional learning community allows for the collaboration necessary for teachers to develop new mathematics teaching pedagogy. Using sociocultural theory as a guide, PD can create collaborative, mediated learning communities to support teacher learning and change.

**Commognition**

The theoretical framework that connects learning and discourse is commognition. Commognition is a learning theory pioneered by Anna Sfard (2007) based on the assumption that thinking can be described as a person’s communication with oneself. It combines communication and cognition and addresses issues around mathematics teaching and learning (Presmeg, 2016). Based on commognition theory, mathematics learning is a process of individual mathematical discourse (Sfard, 2020; Tabach & Nachlieli, 2016). As students’ mathematical understandings develop and change, so does their mathematical discourse. With this theory, the learning of mathematics shifts from memorizing procedures to becoming proficient in a specific and mathematical form of communication (Brown & Hirst, 2007).

Sfard’s (2007) research demonstrates how mathematical discourse is unique and different from other discourses. There are four key features of mathematical discourse. First, mathematical discourse uses mathematics words, which are essential as they help learners describe their world. The second is the
use of visual representations. These representations allow learners to identify the specific objects of their learning and create a common language for communication. Next are the narratives, which can be oral or written. Narratives, such as proof, theories, and definitions, describe things or the relationships of those objects. Last are the routines, patterns, and actions specific to mathematics (Tabach & Nachlieli, 2016). Using detailed records of interactions, Sfard’s research shows that when looking at growth in mathematical discourse, the changes in these four factors can be used to study and determine the extent of student growth.

The Commognitive approach has detailed the circumstances when “commognitive conflict” allows for authentic learning, called the “learning-teaching agreement”:

1. Participants must agree on a common question for the basis of the discourse,
2. The experienced participants (in the classroom, the teacher) leading the discourse must accept their role as leaders, whereas others must be willing to act as followers (learners); the participants must have shared expectations of the learning process. (Sfard, 2020).

There are vital factors that will support or undermine this agreement. First, there is the culture of the classroom. Each unique classroom environment will create different opportunities and, therefore, different kinds of learning (Sfard, 2008). Next, there is the identity of the participants. How the participants identify themselves (self-efficacy) and how others see them (identification) will impact
learning. For example, those seen as competent by their peers often prove to be, while those seen as less intelligent are more likely to fail (Heyd-Metzuyanim, 2015). Last is teaching; what is learned is determined by the opportunities teachers present. It is teachers who model the discourse, both to themselves and the group, and allow for participation by the group (Tabach & Nachlieli, 2016). They are the ones who can determine the access a student has to learn (Sfard, 2020).

Commognition focuses on two types of learning, object-level and meta-level (Cooper & Lavie, 2021). Students independently expand the complexity of their prior mathematical discourse when engaged in object-level learning. Learners often use inquiry or individual exploration to extrapolate what they already know to more complex mathematical situations (Cooper & Lavie, 2021; Sfard, 2020). Meta-level learning is when changes to discourse take place. Learners must change their internal dialog instead of expanding it to fit more complexity (Cooper & Lavie, 2021; Sfard, 2020). This type of learning creates commognitive conflict (Sfard, 2008). This is when the teacher is invaluable. Learners are exposed to a new and different discourse and need assistance navigating it (Cooper & Lavie, 2021). In the elementary classroom, commognitive theory emphasizes the different strategies, discourse tools, and skills teachers need to support student learning (Brown & Hirst, 2007; Sfard, 2008; Tabach & Nachlieli, 2016). To improve students' learning, teachers must develop mathematical language, use visual mediators, extend student narratives, and
work with students to identify and use routines and patterns to improve their discourse.

Commognition is the theoretical framework for Shinno & Fujita’s (2021) research focused on mathematical proving in the elementary classroom. Proving is used to explain and support one's thinking, convince others of a mathematical understanding, and defend or explain problem-solving (Ho et al., 2019). Following Sfard’s (2007) idea that mathematical exploration is part of a routine in which a narrative is presented, researchers looked at how students construct that narrative or explanation. In this case, students looked to prove a mathematical pattern using visual mediators and manipulatives and supported by teacher probing questions. Data was collected using the four critical features of mathematical discourse, word use, visual mediators, narratives, and routines (Sfard, 2007). Results showed that when used by students and supported by teachers, these four features allowed students to develop their mathematical proving. The results demonstrate that the commognitive framework can support student learning through communication with oneself or others.

Erath et al. I (2021) examined the empirical research surrounding language's role in mathematical learning. Using the sociocultural idea that mathematical understanding involves being a member of a community of practice and the commognitive idea that routines are essential in language development, the researchers investigated the instructional routines approaches that support mathematics learning. Through their examination of research studies, they suggest
• students need to be engaged in rich discourse in their class community
• language development routines and norms must be established
• language and multimodal representations must be connected
• scaffolding is necessary to connect language and mathematics learning opportunities
• engaging in rich discourse requires shared meaning-related language

In conclusion, sociocultural and commognitive approaches are essential to support mathematical learning as multiple factors impact language and learning development. First, language learning requires multiple, repeated, and extended learning opportunities (Erath et al., 2021). Second, teachers need to plan and organize classroom discourse in a way where they are the main moderator between the students and the content needs (Venkat et al., 2018). Third, students need scaffolding to support their developing language and extend their thinking to new concepts (Erath et al., 2021). Finally, students must have the opportunity to collaborate and make meaning in a safe and supportive environment (Steele, 2001). Mathematical learning is most effective when teachers and students use discourse to develop mathematical language, collaborate to build a shared understanding, and explain their thinking (Erath et al., 2021; Sfard, 2007).
Conclusion

Examining the effects of PD allows researchers to measure the quality of teachers' learning experiences, the level of teacher change, and how that change affects student learning (Desimone, 2009). While there is significant research on PD, there needs to be a consensus on the specific methods that make it effective (Kennedy, 2016). Research does show that effective PD should be ongoing, at least four months (e.g., Desimone, 2009; Kutaka et al., 2018) and learner-centered (e.g., Murata et al., 2012; Polly et al., 2014). Educational reforms are necessary to improve mathematics education (NCTM, 2014). For these reforms to be successful, we must change how we teach mathematics (Darling-Hammond, 2014; Desimone, 2009; Murata, 2012).

The core of these changes is teacher PD and classroom discourse (Garet et al., 2001; Gee & Whaley, 2016; Gellert, 2012). Significant research in mathematics education has focused on discourse and professional development (e.g., Murata et al., 2017; Murphy, 2016; Ni et al., 2021; Polly et al., 2015). Discourse allows students to put their thinking into words, identifying misconceptions and clarifying their thinking (Baxter et al., 2002; Merces & Sams, 2008; Munson, 2019). For students’ conceptual understanding to develop, teachers must learn to facilitate students in collaborative learning, mathematical support knowledge through discussions, and model reasoning for students (Ball, 1993). To do these things, teachers not only need to develop their mathematical content knowledge but also change their teaching practices (Gomez Zwiep & Benken, 2013; Griffin et al., 2013; Seago et al., 2016)
Additional research is needed to find ways in which PD can be created to assist the teacher in shifting to this new conceptual way of teaching (Heyd-Metzuyanim, 2015; Polly et al., 2015). Improving teaching involves many factors, including teacher content knowledge and perceptions, and is impacted by instructional choices in the classroom (Zwiep & Benkin, 2012). However, how each teacher makes these shifts in their teaching depends on their beliefs about teaching and student learning (Murphy, 2015). Often, PD efforts by well-organized and skillful researchers result in only modest instructional change (Michaels & O’Connor, 2015) because the focus is on effective PD instead of learner-centered PD and meeting the needs of teachers (Kennedy, 2015). While there are ideas for effective PD, the field is still developing ideas about teacher learning and how to help teachers incorporate new ideas into their ongoing systems of practice (Kennedy, 2015). More research is needed to identify and define these specific practices that impact teacher learning and find ways to develop them in other teachers (NMAP, 2008).
Chapter 3 - Action Research Methodology

Problem of Practice

New standards or curricula cannot raise student mathematical achievement by themselves; change depends on the work of schools and teachers to effectively shift their instructional practices (Allensworth et al., 2021). It is widely accepted that PD can improve teaching (Kennedy, 2016; Kutaka et al., 2018). However, not all PD is effective (Guskey, 2003; Kennedy, 2016; Polly et al., 2014). The primary goal of mathematics PD should be to enhance educators' mathematical knowledge, skills, and beliefs to improve students' learning (Guskey, 2003; Kennedy, 2016). Teachers must learn to share mathematical knowledge while facilitating student learning (Gellert, 2013). The National Council of Teachers of Mathematics (2014) has advocated for a change in teaching practices, including using purposeful questions and engaging students in productive discourse. Teachers need to create instruction that centers around students’ mathematical thinking and create opportunities for meaning-making through discourse (Munson, 2019.) Yet, many teachers did not learn with and have not used these practices in their instruction (Jansen et al., 2017; Ni et al., 2021; Smith & Stein, 2018). These teachers will need effective PD to assist them in changing their instructional practices (Desimone, 2009; Kennedy, 2016; Svendsen, 2020). The problem of practice for this study is based on the idea that most teachers at this specific school site do not receive
adequate, sustained PD to support them in implementing conceptual, discourse-based teaching practices (Desimone, 2009; Kutaka et al., 2017; Polly et al. et al., 2015).

**Research Questions**

This mixed-methods case study focused on two key research questions:

1. How does teacher participation in discourse-focused professional development influence conceptual teaching practices?
2. How does teacher participation in discourse-focused professional development influence student discourse during instruction?

**Organization of Research Methodology**

This chapter focuses on the methodology of this mixed-methods, holistic case study. It begins with a rationale for action research and a case study approach. The case study model of action research allowed the researcher to examine and improve mathematics instruction in a specific school by looking at the impact of professional development (PD) in depth for specific participating teachers (Clark et al., 2020; Yin, 2018). The positionality section defines the researchers' role in the study and mitigation for the impact the researcher's role could have on the research. The research design section details the exploratory, mixed-methods case study, setting and time frame for the study, sampling procedure, participant characteristics, and research tools. Research tools are described in detail, and research is shared on the instrument's validity. Next, the procedure is described, giving details on the two-phased PD program and when
and how the research tools are used. The last section of this chapter includes a summary of how the data analysis was completed.

**Rationale for Research Methods**

**Action Research Rationale**

Action research is a process for improving and reflecting on educational practices and gathering evidence to implement change (Clark et al., 2020; Sáez & Gracia, 2022). Action research is a cyclical process of reflection, theory-building, and action (Khler, 2012). As Shulman (1986) shared, “Teacher educators can contribute to the case literature themselves. As they do so, they will begin to feel even more membership in the broader academic guild of professional teachers” (p.12). Introducing the new discourse-based mathematics curriculum, Ready Mathematics (Curriculum Associates LLC, 2020), led to a need for PD for teachers at this site to be successful with mathematical discourse. An action research study allows for the in-depth study of PD and its changes to teachers’ educational practices.

**Action Research Validity**

It is essential to demonstrate validity with any research (Creswell & Creswell, 2014; Feldman et al., 2018; Yin, 2018). Action Research validity criteria were used when conducting this study (Herr Anderson, 2015). Table 3 defines each validity criterion and its application during the research study.
**Table 3.1 Validity of Action Research (Herr & Anderson, 2015)**

<table>
<thead>
<tr>
<th>Validity</th>
<th>Definition</th>
<th>Part of Research Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outcome Validity</td>
<td>The ability of the researcher to move participants toward successful outcomes.</td>
<td>The researcher worked with all participants throughout the PD to support their instruction and use of discourse when teaching mathematics.</td>
</tr>
<tr>
<td>Process Validity</td>
<td>The extent the research allows for ongoing learning.</td>
<td>The researcher used observation and reflection throughout the PD to support and scaffold participants and shift PD to meet learner needs.</td>
</tr>
<tr>
<td>Democratic Validity</td>
<td>The extent that all involved collaborate and have a say in the plan and analysis of the results.</td>
<td>The researcher used participant input and needs to adapt the PD plan to further their learning. Data will be shared with participants to allow their input.</td>
</tr>
<tr>
<td>Catalytic Validity</td>
<td>The extent that the research process assists participants in change.</td>
<td>Individual interviews and classroom observations allowed me to determine if the PD plan assisted participants in changing their beliefs and use of discourse.</td>
</tr>
<tr>
<td>Dialogic Validity</td>
<td>The use of peer review to validate the research findings</td>
<td>The researcher used a critical friend and member checking to review my research, inductive coding, and findings</td>
</tr>
</tbody>
</table>

Herr & Andersons (2015) describe five core goals of action research to distinguish the quality of the research.

- **Generation of new knowledge.** In this study, the new knowledge is developing effective PD that can support changes in teaching practices.
- **Outcomes need to be action-oriented.** In this research, the outcomes were changes in teaching practices.
• Education of both the researcher and participants. This research focused on the teaching of conceptual and discourse-based mathematical teaching practices.

• Results are relevant to the local setting. In this study, the targeted elementary school.

• Sound and appropriate research methodology. This study utilizes an exploratory, mixed-methods case study.

These five goals of action research were combined with validity criteria to determine the quality of this research study (see Figure 3.1).

<table>
<thead>
<tr>
<th>Goals of Action Research</th>
<th>Quality / Validity Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>The generation of new knowledge</td>
<td>Dialogic and Process Validity</td>
</tr>
<tr>
<td>The achievement of action-orientated outcomes</td>
<td>Outcome Validity</td>
</tr>
<tr>
<td>The education of both research and participants</td>
<td>Catalytic Validity</td>
</tr>
<tr>
<td>Results that are relevant to the local setting</td>
<td>Democratic Validity</td>
</tr>
<tr>
<td>A sound and appropriate research methodology</td>
<td>Process Validity</td>
</tr>
</tbody>
</table>

Figure 3.1 – Action Research and Validity Criteria (Herr & Anderson, 2015, p. 67)

The study results are relevant to the specific school site and the district as it explores the impact of the training and new curriculum. They can improve instruction and make informed decisions for all students. The action research process will allow all these goals to be achieved in this study. As Clark et al. (2020) state, the primary reason for conducting action research in an educational setting is to study and improve an educator’s practice. This research aims to strengthen mathematical teaching practices and gather data to help others do the same.
Positionality

In action research, considering the researcher's positionality is crucial when developing the study (Creswell, 2014). Herr and Anderson (2015) define positionality as the relationship between the researcher, the participants, and the research setting. According to their framework, I saw myself as an insider in collaboration with other insiders (Herr & Anderson, 2015) because I was engaged in a Community of Practice (CoP) with other teachers in my building to learn about productive discourse and used that learning to improve our teaching practices. As an insider collaborator, I researched my school and worked with colleagues to improve our teaching practices (Herr & Anderson, 2015). As a reflective practitioner, I engaged with my peers to learn about my teaching practices to become better teachers so my students could become better mathematicians.

As a teacher and researcher, it was essential to recognize how my beliefs might shape the methodology and data analysis (Efron & Ravid, 2013). I had biases that I brought to my research, and I needed to ensure they did not influence my data collection or findings. My previous professional learning on discourse at national mathematics conferences and the current use of discourse in my classroom could affect my views on the training and how teachers could use discourse to improve their teaching. While I learned new discourse methods and used the new curriculum along with the teacher participants, I saw the improvement productive discourse has had on my students’ mathematical understanding and problem-solving; because of these experiences, I came into
this study with the belief that it would be successful with other teachers and students. There were several ways to counterbalance my bias. First, I used standardized data collection, self-reflection methods, peer and participant review, and collaboration strategies to ensure my bias did not impact my findings (Herr & Anderson, 2015). Second, I kept a personal journal detailing my learning, research changes, and data analysis to monitor my bias. Bradbury and Reason (2001) state the importance of noting the choices made during action research and the consequences of those choices. Third, I used objective data collection tools and shared the observation results with the participants. Fourth, interviews allowed teacher participants to share their views on using classroom discourse and their students' mathematical problem-solving growth. This collaborative approach will help focus on the data collected and the impact that can be seen and defined. Lastly, the teacher participants were part of my collaborative team, evaluating the results to ensure their reliability. Participants had open access to the data collection, and their review will help ensure I am accurate in my analysis.

Being a known colleague to the participants was an asset in my research. I have worked with much of the staff for many years. We have built a relationship of trust and support for each other and commonly ask for help and share ideas and teaching strategies to improve student learning. The current research served as a more formalized version of this ongoing collaboration. The prior collaborative relationship allowed participants to feel comfortable with my observations and trust me to listen and support their growth. It is important to
note that all participants in the study were volunteers, and I held no authority over them regarding their job, evaluation, or assessment of student growth. My role as a researcher was the only difference in our ongoing professional relationship.

My positionality as a teacher and a researcher in this study was a factor that must be examined. It was an asset in the relationships that have already been created with the school staff but could have impacted my views of discourse and student problem-solving. Using a research journal, objective data collection tools, and allowing participants to collaborate with the data analysis mitigated this bias and allowed for reliable results.

Mixed-methods Case Study Design Rationale

Case study research investigates real-life events within their typical environment (Ridder, 2017; Schoch, 2020). It is an iterative research process that explains how or why a social phenomenon works (Yin, 2018). This action research utilized a case study design for several reasons. A case study (a) illustrates a problem, (b) indicates a means to solve the problem or sheds light on needed research (American Psychological Association, 2020), and (c) allows for in-depth analysis of a real-world activity or individuals over a sustained period (Creswell & Creswell, 2014; Schoch, 2020; Yin, 2018). Using a holistic approach, this research study focuses on two teachers looking to improve their implementation of discourse-based teaching practices using the Ready Mathematics curriculum (Curriculum Associates LLC, 2020). A holistic approach allows for the data to be compiled to get one overall view of the changes in teachers’ practices (Yin, 2018).
A mixed-methods case study approach was chosen as it allows for multiple and varied data sources leading to a more in-depth understanding of the case (Creswell & Plano Clarke, 2018). Mixed-Methods case studies rely on interviews, surveys, and direct observation (Yin, 2018), all utilized throughout the study. Multiple tools were used to collect qualitative and quantitative data pre-, mid-, and post-PD. Data collected before PD was used in two ways: to help guide the direction of PD to meet teachers’ needs and to determine the impact of the PD on teaching and students’ opportunities for discourse. Post-PD data will be used to assess the effects of PD on teaching practices. By collecting both qualitative and quantitative data pre-and post-PD, the triangulation of multiple data types can lead to a more in-depth understanding of participants’ experiences, changes to their discourse use in the classroom, and mathematical teaching beliefs.

This case study will use a holistic approach (Creswell & Creswell, 2014; Yin, 2018). A holistic case study focuses on a single unit of analysis to show a larger picture of a complex event (Creswell & Creswell, 2014). In this research, the two participants were viewed as a single case in the final analysis. While multiple teachers are part of the study, they are all involved in the same “case” (Yin, 2018). Two participants new to conceptual mathematics participated in situated PD to learn and implement new discourse-based practices in their classrooms. The longitudinal study follows the same participants observed repeatedly over time (Yin, 2018). The data collected is holistic as it does not focus on the individual but on the patterns and themes that arise from the
multiple perspectives of the participants' everyday experiences (Creswell & Creswell, 2014; Yin, 2018). Although data were collected separately, it was analyzed together to show a larger picture of how the PD impacted teaching practices (Creswell & Creswell, 2014).

Following a case study's iterative and flexible nature (Yin, 2018), the research design and PD had a set plan, yet many changes occurred to support participant needs. When using PD contextualized around the classroom, it is essential to use ongoing data collection to determine the focus of learning based on teacher needs and design instruction based on that data (Polly et al., 2015; Polly et al., 2017). Analyzing collected data allows the PD plan to be shifted to meet participant needs. In this case study, teachers struggling with new practices became the focus of the next PD session. For example, one participant asked for additional examples of using high cognitive tasks to solidify learning and increase the use of discourse. Examples and discussions of teaching strategies were the focus of the next session.

The main focus of a case study is to clarify and explain a set of decisions and their impact on a problem (Yin, 2018). Decisions made throughout the study influenced both the data and the findings derived from those decisions. The data analysis will explain the decisions and their impact on the PD and teachers’ implementation of Ready Mathematics (Curriculum Associates LLC, 2020) in their classrooms. A case study model allows the triangulation of qualitative and qualitative data to evaluate the process of implementing contextualized,
discourse-based PD; (Yin, 2018) and explain why and how the PD process impacted teachers’ beliefs and discourse teaching practices.

**Action Research Design**

**Research Design**

This action research study will use a mixed-methods case study approach (Creswell & Creswell, 2014). Mixed-methods action research combines qualitative and quantitative data collection and analysis methods, allowing for more flexibility and applying a multidimensional approach to understanding the research problem (Clark et al., 2020; Creswell & Creswell, 2014). A mixed-methods approach also helped minimize the limitations of each research type (Ivankova, 2015; McCrudden et al., 2019). Using a mixed-methods approach required integrating data from multiple perspectives and data types to evaluate the success of the PD program (McCrudden et al., 2019; Tashakkori et al., 2020). A convergent analysis was selected as the data was collected and analyzed separately, then compared and relating them to each other (Ivankova, 2015; McCrudden et al., 2019; Tashakkori et al., 2020). Data collection, PD, and analysis occurred in several defined phases throughout the study (Ivankova & Wingo, 2018). Figure 3.2 shows the research plan for this study.
School Setting

The study was conducted in an urban K-5 elementary school in Alaska, with a 25% transiency rate, where over 50% of students receive free- or reduced-cost lunches, and 37% were English Language Learners (ELL). Standardized testing shows that about 40% of the students are not proficient in mathematics, a rate slightly higher than the rest of the district and state. The school has two programs: a language immersion Program and a neighborhood program. In the Chinese immersion program, students spend half a day in an English classroom learning mathematics and language arts and half a day in the Chinese program learning Chinese, science, and social studies. The neighborhood program is a typical elementary classroom for students from the neighborhood. There are 18 classroom teachers with experience ranging from 1 – 28 years. The average class size is 23. The school was introduced to the Ready Mathematics curriculum (Curriculum Associates LLC, 2020) in the 2021-22 school year and received
minimal PD for implementation that consisted of an online presentation showing the different features of the program. Curriculum Associations staff presented an informational, mandatory session at the beginning of the school.

**Research Setting**

This study began in the 2021-2022 school year with the introduction of the *Ready Mathematics* curriculum (Curriculum Associates LLC, 2020). Through an email request, all teachers at the school were invited to participate in the study before the start of the year. The proposed research was submitted to the University of South Carolina Internal Review Board (IRB) and given exempt status in February 2021. Eighteen teachers were emailed, eight were interested in the PD, and three agreed to have data used in the study. Participating teachers were provided the IRB consent form, which explained that participation was voluntary. Participants could leave the study at any time, and any data collected would remain confidential. All three teachers who were willing to have data collected were selected to participate in the study. To protect the identity of the participants and setting, pseudonyms are used throughout the study. Contextualized, learner-centered PD sessions were conducted every two weeks throughout the first semester of the school year for a total of 8 sessions over a 4-month semester. Each session was scheduled for 2 hours for 16 contact hours. The focus of this PD was Productive Discourse using *5 Practices for Orchestrating Productive Mathematics Discussions* (Smith & Stein, 2018). One participant left the study in the middle of Phase 1 due to family issues.
In the second semester, the two participating teachers received informal support as they continued to practice implementing mathematical discourse. During this time, data from the observations and interviews were analyzed to decide on shifts needed to proceed with the research. Teacher participants engaged in continued professional learning activities, which is critical for improved instruction (Akiba & Liang, 2016). Additionally, informal conversations and interviews were used to understand teachers’ everyday experiences, which were used to provide ongoing, independent PD (Horn, 2005). Informal learning allowed teachers to overcome the limitations of formal learning opportunities (Jones & Dexter, 2014) and allowed the researcher and participants to focus on individual needs. Informal conversations and collaborative learning allowed teachers to have focused talks on their teaching and beliefs (Akiba & Liang, 2016). Data analysis from the first round of PD and teacher comments in informal conversations led to the decision to start the second round of PD. Two additional teachers were asked to join a PD group, and the focus group interview with all participants led to the creation of a mathematics community of practice (CoP). A community of practice is a group of professionals working together to improve practice (Buysse et al., 2003; Pyrko et al., 2017).

The CoP started at the beginning of the 2022-23 school year (See Appendix E). Due to the iterative nature of the study, the revised research plan was submitted to the University of South Carolina Internal Review Board (IRB) and given exempt status. Participating teachers were provided the IRB consent form, which explained that participation was voluntary. The focus group interview
created an initial PD plan focusing on teacher PD. Sessions would occur twice a month, allowing teachers to implement and reflect on new practices. Individual check-ins occurred within these two weeks to determine the focus of the next session. The sessions ranged from 1-4 hours, depending on the conversations and needs of the participants. Some sessions occurred before or after school, others on teacher in-service days. Discourse or conceptual mathematics content was shared based on teachers’ self-identified struggles at each bimonthly session. Sessions also included a chance to reflect and share successes, concerns, and goal setting. As the sessions continued through the semester, all teachers participated in the sharing of content and new ideas, using their experiences to lead to new mathematical understandings and teaching pedagogies.

**Sampling Procedure**

A convenience sample (Creswell & Creswell, 2014; Jager et al., 2017) was used for this research study for access reasons. For effective PD, the researcher needs to be able to provide ongoing support and observe the teachers’ instruction (Kutaka et al., 2018). For this reason, teachers at the researcher’s school were surveyed and asked to participate in the study. Following IRB exemption, a study description was provided to all primary teachers at Scenic Park Elementary. Of the 12 primary teachers, two volunteered to participate in the study. Teachers did not receive compensation for their participation, but a college professional development credit was available if they applied and paid for it.
Participant Characteristics

Two teacher participants were used in the final reporting of this study. Both were volunteer participants teaching in the selected school.

Participant 1 - Chloe. Chloe was a first-grade teacher who had been teaching for 11 years. She has a master’s degree in education and has taken a few continuing education classes post-degree. She had not used productive discourse before the new curriculum and was anxious about the change. Informal conversations with Chloe showed she had a more traditional teaching style for mathematics instruction with a teacher-centered approach to following the curriculum’s teacher’s guide as best she could. All students work at the same pace on the same workbook page, with the teacher leading the learning.

Participant 2 - Donna. Donna, a second-grade teacher, returned to the classroom after a seven-year break. She has a bachelor's degree in education and had taught intermediate grades. She was new to using discourse but was prepared to try new things. She identified with a more traditional teaching style, saying her goal is to follow the district’s academic plan. She works in a Chinese immersion program and, therefore, has two groups of students, teaching one in the morning and one in the afternoon. She wants to meet student needs but struggles with this new conceptual teaching style. Due to the immersion schedule, she has less time for mathematics instruction than the typical 2nd-grade teacher.
Research Methods

Research Plan

The research for this holistic, mixed-methods case study was completed in two phases spanning two school years (See Table 3.2). The first phase consisted of initial data collection and four months of PD in the fall semester of 2021 (See Appendix D). Over time, engaging participants in multiple sessions of similar structure has increased learning (Darling-Hammond et al., 2017). While the content of the PD sessions changed based on teachers’ needs, the overall structure remained the same in each phase. Mid-PD data were collected two months into the PD sessions. Post-PD data was collected at the end of the formal PD in the fall of 2021, and the spring semester of 2022 consisted of informal support for participating teachers. Individual participant support varied depending on teacher needs. Research shows that informal collaborations and support will continue participant learning outside of formal PD, allowing them opportunities for collaboration and reflection (Darling-Hammond et al., 2017). During the spring 2022 semester, Phase One data was analyzed. This data analysis and informal participant comments showed that an additional phase of PD was needed to support teacher growth. Both teachers shared that they were uncomfortable using discourse in their classrooms and wanted to continue their professional growth.
Table 3.2 Research Plan

<table>
<thead>
<tr>
<th>Phase 1</th>
<th>Phase 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Initial Data Collection</strong></td>
<td></td>
</tr>
<tr>
<td>Discourse Survey</td>
<td>Focus Group Interview</td>
</tr>
<tr>
<td>SBTP</td>
<td>Observation (MCOP² &amp; DIT)</td>
</tr>
<tr>
<td>Individual Interviews</td>
<td></td>
</tr>
<tr>
<td>Observation (MCOP² &amp; DIT)</td>
<td></td>
</tr>
<tr>
<td>Introductory Task</td>
<td>Introductory Task</td>
</tr>
<tr>
<td>Teachers have the opportunity to practice discourse skills</td>
<td>Varied based on participant wants</td>
</tr>
<tr>
<td>Individual Sharing Time</td>
<td>Individual Sharing Time</td>
</tr>
<tr>
<td>Sharing successes/ voicing concerns</td>
<td>Sharing successes/ issues</td>
</tr>
<tr>
<td><strong>Professional Development Sessions</strong></td>
<td></td>
</tr>
<tr>
<td>Content Focus</td>
<td>Productive Discourse (Smith &amp; Stein, 2018)</td>
</tr>
<tr>
<td>Planning Time</td>
<td>Integrating Productive Discourse skills into the curriculum</td>
</tr>
<tr>
<td>Review/ Questions</td>
<td>Summation of content / answering questions</td>
</tr>
<tr>
<td></td>
<td>Review of key content</td>
</tr>
<tr>
<td><strong>Mid-PD Data Collection</strong></td>
<td></td>
</tr>
<tr>
<td>Observation (MCOP² &amp; DIT)</td>
<td>Observation (MCOP² &amp; DIT)</td>
</tr>
<tr>
<td>Individual Interviews</td>
<td>Individual Interviews</td>
</tr>
<tr>
<td><strong>Post-PD Data Collection</strong></td>
<td></td>
</tr>
<tr>
<td>Observation (MCOP² &amp; DIT)</td>
<td>Observation (MCOP² &amp; DIT)</td>
</tr>
<tr>
<td>Individual Interviews</td>
<td>Individual Interviews</td>
</tr>
<tr>
<td>SBTP</td>
<td>SBTP</td>
</tr>
<tr>
<td>Discourse Survey</td>
<td>Discourse Survey</td>
</tr>
<tr>
<td><strong>Informal Support</strong></td>
<td></td>
</tr>
<tr>
<td>Individual support given as needed. Data from informal conversations collected</td>
<td></td>
</tr>
</tbody>
</table>

Phase Two of the research shifted the PD to a Community of Practice (CoP) (See Appendix E). This format creates a learning community where all participants are viewed as learners and teachers, thinking and sharing together.
to support the knowledge and growth of all (Buysse et al., 2003; Pyrko et al., 2017). As a CoP, topics of discussion and content shared were based on participant needs or suggestions. In this phase, data again were collected pre-, mid-, and post-PD, but in this phase, analysis occurred during the PD to help determine the content focus of the sessions (See Appendix F).

**Data Collection Instruments**

Many factors are involved in effective PD that can impact implementing standards-based mathematics programs in the elementary classroom (Desimone, 2009; Kennedy, 2016; Svendsen, 2020; Darling-Hammond et al., 2009). Qualitative and quantitative data collection tools will be used in an exploratory mixed-method design. Each tool was aligned to the research questions and gave insight into a different implementation aspect, leading to a more rounded and complete picture of the impact of contextualized, discourse-based professional development. (See Table 3.3)

**Discourse Questionnaire**

Adapted from a *Ready Mathematics* (Curriculum Associates, 2020) and an Anchorage School District-created survey, this Google form (Google Forms, 2022) questionnaire focuses on teachers’ views, beliefs, and use of discourse in the classroom. It was completed pre-and post-PD to determine teachers' perception of personal changes in their beliefs and instruction surrounding discourse (see Appendix A).
Table 3.3 Data Collection Alignment

<table>
<thead>
<tr>
<th>Research Question</th>
<th>Data Collection Tool</th>
<th>Data Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. How does teacher participation in discourse-focused professional development influence conceptual teaching practices?</td>
<td>Qualitative: Discourse Questionnaire MCOP² - comment section Participant interview Focus Group Interview Informal conversations Quantitative: MCOP² DIT SBTP</td>
<td>Inductive coding with clarification from interviews and informal conversations</td>
</tr>
<tr>
<td>2. How does teacher participation in discourse-focused professional development influence student discourse during instruction?</td>
<td>Qualitative: MCOP² - comment section Participant interview Focus Group Interview Informal conversations Quantitative: MCOP² DIT</td>
<td>Inductive coding with clarification from interviews and informal conversations</td>
</tr>
</tbody>
</table>

Standards-Based Teaching Practices Survey (Ross et al., 2003).

The Standards-Based Teaching Practice (SBTP) survey was created as a cheaper and more efficient means to assess reformed-based mathematics instruction through teacher self-reporting on standards-based teaching practices (Ross et al., 2003). Research shows that self-reporting can be reliable for assessing teaching practices (Stepick, 2001; Mayer, 1999). The SBTP is a 20-question survey assessing nine different dimensions of reform-based teaching (1) program scope, (2) open-ended student tasks, (3) construction of mathematics ideas through discovery, (4) teacher's role, (5) use of manipulatives.
and tools, (6) student-student interaction, (7) student assessment, (8) teacher’s conceptions of mathematics as a discipline, and (9) raising student confidence in mathematics. Teachers rank their conceptual mathematics use on a Likert scale of one to five. This measurement tool has been researched and found to be a reliable and valid measure of reform-based teaching practices (Ross et al., 2003). Participants were given the survey before PD to determine their current practices. Results from the SBTP were also used to guide the PD plan. The survey was completed again post-Phase One and Phase Two. Results were compared to determine changes in pre-post teachers’ practices.

The SBTP uses Likert scale ranking beliefs from 1-5, with one being strongly disagreed and five strongly agreed. Twenty questions were included spanning nine dimensions of conceptual mathematics. For most responses, one rating shows a traditional belief in mathematics instruction, and five shows conceptual mathematics beliefs. The reverse is true for problems six, eleven, fifteen, sixteen, eighteen, nineteen, and twenty. When calculating the results, these problems are scored in reverse (See Figure 3.3).

<table>
<thead>
<tr>
<th>Item</th>
<th>Questions</th>
<th>Dimension</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>I like to use math problems that can be solved in many ways.</td>
<td>D2</td>
</tr>
<tr>
<td>2</td>
<td>I regularly have students work through real-life math problems that are of interest to them.</td>
<td>D2</td>
</tr>
<tr>
<td>3</td>
<td>When two students solve the same math problem correctly using two different strategies, I have them share the steps they went through with each other.</td>
<td>D6</td>
</tr>
<tr>
<td>4</td>
<td>I tend to integrate multiple strands of mathematics within a single unit.</td>
<td>D1</td>
</tr>
</tbody>
</table>
I often learn from my students during math time because my students come up with ingenious ways of solving problems I have never thought of.

It is not very productive for students to work together during math time. (Note negative)

Every child in my room should feel that mathematics is something he/she can do.

I integrate math assessment into most math activities.

In my classes, students learn math best when they can work together to discover mathematical ideas.

I encourage students to use manipulatives to explain their mathematical ideas to other students.

When students are working on math problems, I put more emphasis on getting the correct answer than the process followed. (Note- not conceptual based)

Creating rubrics for math is a worthwhile assessment strategy.

In my class, it is just important for students to learn data management and probability as it is to learn multiplication facts.

I don’t necessarily answer students’ math questions but rather let them puzzle things out for themselves.

A lot of things in math must simply be accepted as true and remembered. (Note- not conceptual based)

I like my students to master basic mathematical operations before they tackle complex problems. (Note- not conceptual based)

I teach students how to explain their mathematical ideas.

Using computers to solve math problems distracts students from learning basic math skills. (Note- not conceptual based)

If students use calculators, they won’t master the basic math skills they need to know. (Note- not conceptual based)

You have to study math for a long time before you see how useful it is. (Note- not conceptual based)

---

**Figure 3.3 – Standards-Based Teaching Practices (Ross et al., 2003)**
Mathematics Classroom Observation Protocol (Gleason, 2015).

Observing people in a specific setting provides a contextual understanding of behaviors, actions, and relationships (Clark et al., 2020). Observations allow the researcher to collect data that cannot be found with any other measure (Clark et al., 2020). The Mathematics Classroom Observation Protocol (MCOP²) tool was selected to gather the observation data as it supports quantitative and qualitative data collection. Quantitative data was collected on discourse-related practices in the observed lesson. Qualitative observational notes provided additional context to the data (Creswell & Creswell, 2014). Observations were completed by the researcher and occurred three times in each phase, pre-, mid-, and post-PD. All participant observations were videotaped. Videotaping allows teacher participants to review and reflect on their instruction, enabling researcher review opportunities (Feldman et al., 2018).

Six classroom observations were conducted for each teacher, three each year, to identify changes in discourse teaching practices. This tool uses a Likert scale, ranging from 0 (not observed) to 3 (proficient use of the practice), to rate the use of discourse-related teaching practices in the observed mathematics lessons. Descriptive statistics were gathered to describe the teaching practices of both teachers throughout the PD implementation. The adapted MCOP² had ten different mathematical practices focusing on discourse-related practices:

1. Students were engaged in mathematical activities.
2. Students critically assessed mathematical strategies.
3. The lesson involved fundamental concepts of the subject in promoting relational/conceptual understanding.

4. The lesson included tasks with multiple paths to a solution or multiple solutions.

5. The teacher’s talk encouraged student thinking.

6. There was a high proportion of students talking related to mathematics.

7. There was a climate of respect for what others had to say.

8. In general, the teacher provided wait time.

9. Students were involved in communicating their ideas to others (peer to peer).

10. The teacher uses student questions/comments to enhance conceptual mathematical understanding.

These items were selected as they all related to discourse-based teaching practices. Other items were beyond the scope of this research and were not used. The score scale ranges from zero to three. A zero shows the practice was not observed, and a three means a proficient use of the practice. There is no ranking for advanced teaching practices.

**Dialogic Inquiry Tool (DIT, Reznitskaya & Glina, 2018)**

Discursive interactions vary throughout mathematics instruction (Reznitskaya & Glina, 2018). These interactions are influenced by teacher beliefs, knowledge, and mathematical content (Kathard et al., 2015). The Dialogic Inquiry Tool (DIT) categorizes discourse interactions into monologic,
transitional, and dialogic (Reznitskaya & Glina, 2018). The DIT gathers data on both teacher and student interactions. Teacher interactions are categorized by authority, questioning, feedback, and metalevel reflecting/connecting. Student interactions are categorized by explanation and collaboration. This tool was used during observations to determine the level of discourse interactions following PD.

The DIT is a research-based tool used to analyze the type of discursive interactions used in the classroom. Interactions are ranked from monolithic to dialogic, with transitional as a middle rank (Reznitskaya et al., 2012). Monolithic interactions indicate that the teacher controls the interactions and the students are receptors of information (Kathard et al., 2015). Dialogic interactions indicate the use of social interactions where teachers and students take turns creating meaning together (Kathard et al., 2015). Transitional interactions are the mediatory level between the two interactions where teachers release some control and engage in discourse with students (Reznitskaya et al., 2012). The DIT uses six indicators to analyze discursive opportunities (Figure 3.3).

Frequency data were also collected during the observations to determine the number of students participating and the time spent in student-student discourse. If the ultimate goal of PD is improved student learning (Brandefur et al., 2021; Guskey, 2003), then student use of discourse is an important measure.
Qualitative Participant Interviews (See Appendix G)

An interview is one of a case study's most important data sources (Yin, 2018). Interviews are used to find explanations of participants’ actions and learning, gain insight into participants’ perspectives (Yin, 2018), and provide indirect information through participants' views (Creswell & Creswell, 2014). Semi-structured participant interviews were conducted after classroom observations to allow teachers to give personal information on their teaching decisions (McGee et al., 2013). A semi-structured interview is an exploratory interview based on a guide but allows for open conversation (Ruslin et al., 2022). While the interviews followed an interview protocol with open-ended questions (See Appendix 3), they were fluid, allowing participants to share their reflections, thinking, and explanations (Yin, 2018). Individual interviews took place pre- and
post-PD. Holistic, inductive coding (Miles et al., 2014) was used to find themes and patterns in the data.

Individual teacher interviews provided additional insight into the choices and motivations behind the observed lessons. Participants had the opportunity to explain the lessons from their point of view, describe their choices, and set goals for future mathematics teaching practices. A semi-structured interview process was used, allowing for flexibility to allow the participant to feel comfortable in their reflections and the researcher to dive deeper into discovery (Magaladi & Berler, 2020). Inductive coding allowed the participants’ perspectives and language to be part of the codes (Miles et al., 2014). After initial coding, member checking (Brit, 2016) was used to ensure the participants’ reflections were accurately recorded.

**Informal Conversations**

Informal support was given by the researcher to the participants after the formal PD session. The opportunity for teachers to continue their learning outside of formal support contributes to sustained learning (Darling-Hammond et al., 2017). To coincide with this support, informal interviews were used. Informal interviews are more like conversations and can produce more natural data (Swain & King, 2022). These conversations were either a part of one-on-one support sessions or informal conversations stemming from collegial interactions. While often unplanned, these opportunistic moments can present authentic and reflective information that would not be shared in a formal interview (Fujii, 2015). Swain & King (2022) contend that informal conversations are as valid as formal
interviews and can openly share their ideas and perceptions. Notes about informal conversations were recorded in the researcher's journal for data analysis.

**Focus Group**

Focus groups were conducted in the second phase of the study. Focus group interviews are a research technique that collects data on a topic the interviewer selects (Morgan, 1988). Focus groups were selected as they are flexible, aid recall, and stimulate elaboration, allowing participants' interactions to reveal more profound and complete information (Fontana & Frey, 1994). The focus groups were used for two purposes. First, to create a PD plan to meet the CoP learning needs and second, as data on changes in teachers' beliefs and practices. The focus group met formally two weeks before PD to develop CoP norms, determine teacher needs and develop an action plan for the beginning of the CoP. The CoP concluded each PD session with a focus group discussion to set goals and determine teacher needs for the next PD session. Each focus group was semi-structured, beginning with researcher-directed questions and concluding with open discussion to allow for participants to share additional thoughts and ideas.

**Data Collection Procedures**

The professional development for this study began before the 2021-22 school year with a district-wide, mandated, 6.5-hour online PD training for implementing our new mathematics curriculum, *Ready Mathematics* (Curriculum Associates, 2020). *Ready Mathematics* is a standards-based program with a
discourse focus (Curriculum Associates, 2020). This training focused on using the curricular tools provided by the program. There was no district-provided PD on conceptual mathematics or using discourse in mathematics instruction. Teachers at the participating school were invited to take a school-based course, “Productive Discourse in the Elementary Classroom,” taught by the researcher, and to participate in this study. Professional development credit was available from the local university. Following the IRB exemption, a study description was provided to all teachers. Eight teachers elected to only take the course, with three agreeing to participate in the research. The three teachers who volunteered to participate in the research study followed up with an individual interview and goal-setting session. This 30-minute interview allowed teachers to share their concerns about implementing the new curriculum in the classroom and set personal goals for their mathematics instruction.

Participants completed the SBTP (Ross et al., 2003) to determine their current perception of their teaching practices. Effective PD must be grounded in teachers’ current practices (Gomez Zwiep & Benken, 2013). This survey was used as a starting place to lead participants toward new practices (Murata et al., 2012). Using data from the interviews and surveys, the researcher adopted the PD plan (See Appendix B) to meet the needs of the participants, as research shows that teacher characteristics and beliefs impact curriculum implementation and should be considered when planning effective PD (McGee et al., 2013). A research plan should be flexible in design to allow data to emerge and find the best data to address research questions (Clark et al., 2020). Teachers also want
concrete and practical ideas directly related to their daily teaching practices (Kennedy, 2016). For these reasons, the basic format of the PD plan did not change, but the content and activities of the PD were contextualized around teachers’ practices.

1. PD sessions Participants attended bimonthly one-hour PD sessions from August 2021- February 2023.
   a. Content focus
      i. Phase 1 (See Appendix D): PD consisted of a discourse focus on learning strategies to support student discourse: (Smith & Stein, 2018); PD focuses on specific instructional practices to increase teachers’ use of that practice in their classroom. (Darling-Hammond, Wei, Andree, Richardson, and Orphanos, 2009) In year 1, Smith & Stein’s (2018) 5 Practices for Orchestrating Productive Mathematics Discussions was provided for each teacher and used as the PD plan's basis.
      ii. Phase 2: (See Appendix F) The content and discourse were determined based on the directions of CoP needs.
   b. Participant sharing: The sharing of teacher experience leads to reflection, action, concrete reflection, and change. (Papa & Jassica, 2011)
   c. Planning for future lessons: Research from Murata et al. (2012) shows that teachers benefit from planning lessons, teaching them,
and experiencing student learning. This allows them to examine their teaching practices critically.

2. Classroom observations using the MCOP² occurred pre-, mid-, and post-PD to allow the participants and researcher to identify changes in teaching practices and the use of discourse in mathematics instruction. Following Desimone et al.’s (2016) recommendation, observations were scheduled during lessons teachers believed would demonstrate the use of discourse in their classroom. Observations were videotaped to allow for further review of the lesson.

3. Individual interviews occurred following the observations allowing the opportunity for reflection and a change in the PD plan: When teachers reflect on their practice, there is an opportunity for change (Svendsen, 2020). Learning is more productive if it is reflective and collaborative (Kennedy, 2016), so interviews were used for data collection and teacher reflection. The interview began with researcher questions, and then participants shared their thinking, asked for feedback, and made plans for future lessons.

The specific goals and objectives of the PD sessions were adapted throughout the study to meet learners where they were and challenge them to improve their instruction. Still, the basic format and mathematical and discourse-based content stayed the same. Mathematical knowledge and beliefs are not only influenced by one another—but they also affect instruction in complex ways (Kutaka et al., 2016). Professional development efforts must be based on
teachers’ needs, related to their practice in their school, provide time, and be thoroughly planned (Villegas-Reimers, 2003).

At the end of the study, a final classroom observation and participant interview was completed. Participants had the opportunity to share their thoughts on the PD sessions, the challenges they experienced with using discourse in their classrooms, and their personal beliefs about mathematics teaching. Having a teacher's voice be part of the data analysis is vital. As part research collaborators, the participants reviewed and reflected on the data, ensuring the analysis was accurate and valid (Creswell & Creswell, 2014). (See Appendix G)

Data Analysis

Holistic case study research involves a detailed description of the setting and individuals followed by an analysis of the emerging themes, patterns, or issues surrounding the changes in teaching practices (Creswell & Creswell, 2014). Data analysis was completed throughout the research study. Some analysis was conducted during the study to allow for the adaptation of the PD plan to meet the participants' needs. Data triangulation of the SBTP, classroom observations, and individual interviews was used for formative analysis to identify participant needs (Yin, 2018). Triangulation allows for the clarification of analysis and development of meaning (Ridder, 2017). For example, if observational data showed participants mainly use teacher-student discourse in instruction, the SBTP would be examined to see if this was part of their original teaching practices. The forthcoming PD would be adapted to include instruction on how and why to use student-student discourse.
Following the implementation of the PD, data analysis happened in three phases (Creswell & Creswell, 2014). First, inductive coding of the qualitative data from classroom observations and participant interviews was completed to determine critical themes. Next, the quantitative data were analyzed using descriptive statistics. Last was the convergent analysis using a side-by-side comparison (Creswell & Creswell, 2014), where data from all sources were analyzed to determine patterns. Using data triangulation and pattern matching, key themes were identified to assess the impact of the contextualized CoP professional development on the use of mathematical discourse in the classroom.

**Coding Procedures**

Coding was used to analyze the qualitative data collected from interviews, observations, and informal conversations. Coding organizes qualitative data into chunks to derive meaning from the data (Creswell & Creswell, 2014; Linneberg & Korsgaard, 2019; Miles et al., 2014). These segments are used to find themes and answer research questions (Miles et al., 2014). Coding allows the researcher to select the relevant parts of the data to share with the reader (Linneberg & Korsgaard, 2019). Coding also forces the researcher to revisit data, allowing deeper analysis than the initial impressions gathered during data collection (Linneberg & Korsgaard, 2019). An inductive coding process was used for both research questions, which allowed codes to be developed directly from the collected data instead of predetermining codes (Linneberg & Korsgaard, 2019). Inductive coding keeps the data mirroring the participants’ thoughts instead of the
researchers' interpretations and captures the complexity of the data (Linneberg & Korsgaard, 2019).

The three-cycle coding process was used for analysis (Williams & Moser (2019). This model is a cyclical process requiring multiple data reviews. Open coding was used for the first cycle of coding. Open coding allows the researcher to identify themes and categories of information (Linneberg & Korsgaard, 2019; Williams & Moser, 2019). In the open coding cycle, the researcher reviewed recordings of the interviews and noted words and phrases of importance in a spreadsheet. Pattern coding was used for the second coding cycle to refine further and organize the data (Williams & Moser, 2019). Pattern codes pull together data from the first cycle and allow the researcher to continue analysis during data collection (Williams & Moser, 2019). In this cycle, the open codes were organized into groups to identify patterns within the codes. This analysis allowed the researcher to make data-informed amendments to the PD and support participants using new teaching practices. Selective coding was used for the third cycle (Williams & Moser, 2019). With selective coding, the researcher selected and aligned the pattern data to find themes and define the case studied (Williams & Moser, 2019). These analysis cycles allowed the researcher to delve deeply into the data and for themes to be developed (Williams & Moser, 2019).

Data were coded individually for each participant throughout the coding cycles, then compiled to create a holistic view of the data (Yin, 2018). This aligns with the research methodology of a single-case study with two participants (Yin, 2018). A holistic view allows the researcher to find coherence in the data and
develop a theory for change or an understanding of what occurred (Feldman et al., 2018). This coherence is used for explanation building, explaining how and why teaching changes did or did not occur (Yin, 2018). To conclude the analysis, this study’s findings were compared with prior research results (Yin, 2018).

Member checking and a critical friend were used to reduce potential bias in coding (Brit et al., 2016; Feldman et al., 2018). Member checking allows the participants to view and reflect on the analysis to ensure validity (Creswell & Creswell, 2014). After the study, both participants reviewed the data allowing them to share their thoughts and insights on the discourse and changes in teaching practices. They also reviewed Chapter 5 to ensure the findings accurately represented their experience. These conversations helped to minimize research bias and increase the validity of the findings (Creswell & Creswell, 2014).

Additionally, a critical friend helped provide meaningful feedback and move the research forward (Feldman et al., 2018). While an outsider to the research, a critical friend helps the researcher to clarify actions, critique ideas, and find gaps in understanding or analysis (Feldman et al., 2018). Throughout the study, a critical friend was used to give feedback, offer suggestions and check for bias within the research. The critical friend was a member of the same dissertation cohort as the researcher and knew the process to offer support and guidance on the research, but came from a different background allowing for a different perspective on the research and a critical eye on the analysis.
Evaluating the Professional Development Plan

The PD plan implemented in this study will impact the results of this study. Guskey’s Model of Evaluating Impact (2002) will be used to evaluate the impact of the PD plan and its effectiveness. This model has five levels for measuring the impact of PD:

1. participants’ perceptions
2. participant learning
3. organizational support and change
4. participant use of new knowledge and skills
5. student learning outcomes

Levels one, two, four, and five will be the focus of this study. Interviews and surveys were used to determine the impact of participants’ perceptions. Acquisition and use of knowledge and skills were evaluated through observations, surveys, and interviews. Student learning outcomes were based on the change in discourse opportunities. Organizational support and change were beyond the scope of this study.

Plan for Reflecting with Participants on Data

As an insider collaborating with other insiders (Herr & Anderson, 2015), sharing the data and analysis with the participants was essential. As collaborators, we were working together to improve practice. Access to the data allowed opportunities for participant reflection and assured that data analysis is accurate to their teaching situations (Creswell & Creswell, 2014). By engaging my participants in the research process, they actively changed their instruction
and helped ensure the research process’s reliability and validity (Herr & Anderson, 2015).

After each videotaped observation, an individual interview was completed to allow teachers to reflect upon their teaching practices. This served three purposes. First, they could see what they and their students were doing during instruction. Often what we think is happening in our instruction is different from reality. Secondly, it allowed an opportunity for reflection. Based on reflection and feedback, participants could plan for changes in their teaching practices (Svendsen, 2020). Lastly, the semi-structured interview allowed participants to share their thoughts while teaching (Ruslin et al., 2022) and communicate what guided their discourse decisions. This interview allowed for collecting the teacher’s perspective (Clark et al., 2020).

The final data analysis was shared with the participants during a closed individual interview. Through member checking, it was determined that the findings were accurate from the participant and researcher's point of view (Creswell & Creswell, 2014). This process validity helps assure not only that the research process stays true to the research plan and goals but helps continued learning for the researcher and participants (Herr & Anderson, 2016).
Chapter 4 – Results

This chapter presents the results from the quantitative and qualitative data collected for the study. It begins with an overview of the study and the research questions. A holistic, exploratory, mixed-methods case study approach was selected for this study as it enables the researcher to focus on multiple factors in teaching, professional development, and its impact on teaching practices (Khler, 2012; Yin, 2018). Quantitative and qualitative data were integrated to show different perspectives on changes in mathematical discourse and teaching practices (Tashakkori et al., 2021). The following section contains a summary of the study’s data analysis. A conclusion ends this chapter, summarizing the key findings of this research study.

Overview of Study

The National Council for Teachers of Mathematics (NCTM, 2014) has stressed the need to change mathematics instruction from traditional to more conceptual practices. Despite efforts by researchers and teacher leaders, change has yet to happen, and procedural mathematics teaching is still common in education (Anderson et al., 2018; Murata et al., 2017). Changing instruction to a new kind of mathematics teaching is challenging (Jansen et al., 2017). Teachers often need help understanding what productive discourse in the classroom looks like and how to implement discourse into mathematics instruction (Huffard-Ackles et al., 2004; Murphy, 2015). This mixed-methods case study focused on the
impact of sustained professional development on teachers’ implementation of a discourse-based mathematics curriculum. Data were analyzed to address the following research questions:

1. How does teacher participation in discourse-focused professional development influence conceptual teaching practices?
2. How does teacher participation in discourse-focused professional development influence student discourse during instruction?

Classroom observations, teacher surveys, and interviews were used to gather data and triangulate the findings to explore the research questions.

Overview of Professional Development Design Plan

Professional development (PD) occurred in two phases across two years, starting in the fall of the 2021-22 school year and continuing through the 2022-23 school year.

Phase 1

In Phase 1, PD began with a semester-long PD class, starting in August and ending in December, with eight sessions and 16 hours of direct contact time with additional indirect support (See Appendix D). The PD focused on improving participants’ understanding of mathematical discourse and increasing the use of productive discourse in their classrooms. The PD emphasized teaching practices for orchestrating productive discourse in the classroom and how the practices can impact students’ mathematical understanding (see Appendix 5). In the spring of 2022, participating teachers received more informal one-on-one support from the researcher. This support varied on the teacher’s needs, questions, and
student challenges. Data analysis from Phase I and participating teaching requests indicated a need for continued PD, resulting in the formation of Phase 2 PD. While both teachers increased their use of discourse, observations show neither demonstrated proficiency on the MCOP² (2.1 and 2.0, with 3.0 being proficient), and both participants demonstrated mostly transitional interactions on the DIT. The SBTP survey (3.55 and 3.25, with 5.0 being the desired result) and teacher interviews show that participants remained hesitant to allow students the opportunity for open discourse. The focus was on using procedures to get the right answer. Table 4.1 shows a summary of the Phase 1 data.

*Table 4.1 Summary of Phase 1 Data*

<table>
<thead>
<tr>
<th>Data Tool</th>
<th>Post-Phase 1 PD</th>
<th>Desired Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCOP²</td>
<td>Chloe 2.1</td>
<td>Donna 2.0</td>
</tr>
<tr>
<td>SBTP</td>
<td>3.55</td>
<td>3.25</td>
</tr>
<tr>
<td>DIT</td>
<td>mostly transitional</td>
<td>mostly transitional</td>
</tr>
</tbody>
</table>

**Phase 2**

Two additional teachers requested to join the PD for the 2022-23 school year (See Appendix E). A PD plan was created to continue to support and meet teacher needs. Data from a focus group interview indicated that a learner-centered community of practice (CoP) would be used for the second year of PD. In the focus group, teachers shared the need to watch others teach using discourse. They shared their frustration with needing to understand what it would
look like and what they and the students should be doing. As they talked, they bounced ideas off each other and elaborated on ideas. One participant responded, “We need something like this. A place where we can talk and share ideas, but with you to help us know if we are doing it right.” Another responded, “Yes, you can show us, and then we can try it and talk about it.” Several participants stated they wanted to work as a group “to learn how to teach mathematics better.” We committed to meeting for the first semester and then deciding on future learning.

The CoP group officially met twice a month from August to February 2023. The sessions ranged from 1 hour to 3 hours, based on the day and needs of the group. Based on learner-center research, PD sessions allowed teacher collaboration, supported teacher reflection, provided content and pedagogical knowledge, and allowed teacher ownership of their personal development (Polly et al., 2015). Each session had a fundamental discourse or mathematics focus based on the participants' reflections. Between sessions, many individual meetings between participants occurred. Participants would share their successes and failures, as well as plans and ideas of things others could try in their classroom. The goal was for everyone to learn new mathematics practices to support student discourse. All participants had knowledge that could help others meet this goal.

**Summary of Data Collection**

Data collection occurred throughout the intervention process from August 2021 to February 2023. Data were used in two ways: (1) To determine teacher
PD needs and adapt the PD plan (2) To determine the impact of PD on teaching practices and the use of discourse in the classroom. (see Figure 4.1) Complete data is found in Appendix G.

**Figure 4.1 – Data Collection Timeline**

**Phase 1**

**Pre-PD.** Before the PD intervention, teachers completed a discourse survey, Standards-Based Teaching Practice (SBTP), and an individual interview. These data were used to determine a baseline pre-intervention and to guide PD planning. Classroom observations were conducted using an adapted Mathematics Classroom Observation Protocol (MCOP², Gleason, 2015) and Dialogic Teacher-learner interactions (DIT, Reznitskaya & Glina, 2018) to gather baseline data on the teaching practices and student opportunities for discourse during mathematics instruction. The MCOP² was shortened to include only the discourse-related questions (see Appendix G).

**Mid-PD.** Mid-PD observations using the MCOP² and DIT were used to determine changes in teaching practices and students’ opportunities for discourse during instruction. During PD sessions, teachers were allowed to share
personal reflections on their teaching practices, struggles, and successes. These data were used to adapt the PD plan to meet teacher needs.

**Post PD.** At the PD's end, teachers completed the discourse survey, SBTP, and an individual interview. The concluding interview was conducted to get teacher input into the changes they felt occurred in the classroom. These qualitative data allowed for personal experience to be shared and analyzed as a part of the data. A final observation was conducted using the MCOP² and DIT.

Teachers were asked to keep a personal journal with at least one reflection between each PD session throughout the PD intervention. This journal was used as a note-taking guide, personal reflection, and reminder of their journey into the use of discourse in their classroom. Participants used their journals in the final interview as a reminder of their growth.

Informal data was collected in the 2nd semester of the 2021-22 school year. Individual, informal discussions occurred as teachers received individual support and shared their reflections.

**Phase 2**

**Pre-PD.** A focus group interview was conducted to determine teacher needs and a focus for the PD sessions. Teachers completed the discourse survey and SBTP to determine current teaching practices. Classroom observations were also conducted using an adapted MCOP² and DIT to gather baseline data on the teaching practices and student opportunities for discourse during mathematics instruction.
Mid-PD. Mid-PD observations using the MCOP² and DIT were used to determine changes in teaching practices and students' opportunities for discourse. During PD sessions, teachers were allowed to share personal reflections on their teaching practices, struggles, and successes. These data were used to adapt the PD plan to meet teacher needs.

Post PD. Teachers completed the discourse survey, SBTP, and participated in a focus group at the PD's end. A final observation was conducted using the MCOP², and DIT was completed. Individual interviews were used to add participants' perspectives on their final observations and changes in teaching practices.

Data Collection Findings

Research Question 1

Data from all three tools supported the findings for the first research question: How does teacher participation in discourse-focused professional development influence conceptual teaching practices? Data is organized by the collection tool. Each section starts with an overview of the tool, followed by detailed results.

Mathematics Classroom Observation Protocol for Practices (MCOP²)

Data Collection Results

Phase One – PD Observations. The first phase of PD focused on using Productive Mathematical Discourse Strategies (Smith & Stein, 2018). Observations were completed to determine participants' use of discourse and
standards-based teaching practices (See Appendix A). Observations allowed for unbiased data collection of teaching implementation of new practices (Desimone, 2009).

**Donna – First observation.** Donna’s first observation occurred pre-PD and lasted 22 minutes of a mathematics lesson. Following the Ready Mathematics teacher's guide (Curriculum Associates LLC, 2020), Donna’s lesson goal was “to use bar and picture graphs to solve problems.” Donna projected a copy of the student page on the board and discussed each problem with the students, ensuring they had the correct answer. Donna asked questions about the graph, and students raised their hands to answer. As the lesson continued, Donna walked around to see if each child could read the graph and had the correct answer on their page. As the observation ended, students moved on to completing the independent part of the lesson. Analysis of observational notes indicated that the observed lesson focused on producing the correct answer. While SMP 4, a model with mathematics, was used with the graph, students were not given the opportunity to develop conceptual mathematical understanding. Students spent most of the lesson answering Donna’s direct lower-level questions or copying the correct procedure and answer from the board. On the MCOP², Donna’s mean score was 0.7, indicating that Donna is using traditional teaching practices in her mathematics lessons (see Table 4.1).

**Second Observation- Donna.** Donna’s second observation occurred mid-PD of Phase One, lasted 27 minutes, and focused on fact families. The goal was for students to understand that if they know an addition equation, they can
solve a related subtraction problem. Donna modeled how fact families are related, and then the students copied the procedure. Next, she guided the discussion and asked students to share the equations that were part of the fact family, modeling a procedure with student support.

Students then worked on writing number sentences. When it seemed that most were done, Donna asked students to come up and share an equation and what they did. The class was asked if they agreed or disagreed with the equation. While students were asked to come and share their work, all the questions came from Donna, and answers were directed back to Donna. As the observation concluded, students independently completed a worksheet by writing fact family equations. Observational notes show that all students were engaged in the lesson and could accurately write fact families in this teacher-directed lesson. Using SMP 7, look for and make meaning of structure, students used the fact family concept to write equations. All discourse was teacher-student and focused on independently following the procedure shared by Donna. On the MCOP², Donna’s mean score was 1.3, showing a shift toward more conceptual-based practices (see Table 4.1).

**Third Observation- Donna.** Donna’s third lesson following the Phase One PD sessions focused on comparing measurements and lasted 30 minutes. Students were challenged to determine which unit would have more when measuring the same items. While Donna still controlled the lesson and guided students toward the correct answer, she did allow students time for peer-to-peer discourse to share their thinking. Following the peer discourse, students shared
Donna asked them to share their answer and explain why they thought it was correct. When students were asked to share, Donna

*Table 4.2 Observational Data of Donna’s Phase 1 Observations.*

<table>
<thead>
<tr>
<th>MCOP² Practice</th>
<th>Obs. 1</th>
<th>Obs. 2</th>
<th>Obs. 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students were engaged in mathematical activities.</td>
<td>2</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Students critically assessed mathematical strategies.</td>
<td>0</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>The lesson involved fundamental concepts of the subject in promoting relational/conceptual understanding.</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>The lesson included tasks with multiple paths to a solution or multiple solutions.</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>The teacher's talk encouraged student thinking.</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>There was a high proportion of students talking related to mathematics.</td>
<td>1</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>There was a climate of respect for what others had to say.</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>In general, the teacher provided wait time.</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Students were involved in communicating their ideas to others (peer to peer).</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>The teacher uses student questions/comments to enhance conceptual mathematical understanding.</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td><strong>Mean Score</strong> <em>(Score of 3 is proficient)</em></td>
<td>0.7</td>
<td>1.3</td>
<td>2.0</td>
</tr>
</tbody>
</table>

*See complete data in Appendix H.*

Donna chose those students who could give the “right” answer, often stating, “That is what I was looking for.” Analysis of observational notes indicated that Donna used peer-peer discourse to allow students to discuss different measures. Several SMPs were supported in this lesson. SMP 3, construct viable arguments and critique the reasoning of others; SMP2, reason abstractly and quantitatively; and SMP 6, attend to precision, were needed as students compared measures.
Students shared their ideas with each other and were allowed to explain their thinking. On the MCOP², Donna scored an average of 2.0, showing an increased use of discourse and conceptual practices (see Table 4.2).

**First Observation- Chloe.** In a review session, Chloe’s first observation occurred pre-Phase One PD and lasted 24 minutes. The lesson focused on “adding in any order.” Students were given two digits and solved the problem. The lesson goal was to understand the communicative property of addition. Chloe followed the teacher’s guide as she presented the lesson to the students. She read the first mathematics problem, and students attempted it in their book. After a short wait time, she asked for the answer. Chloe then explained the problem and how you could add either way and get the same answer. Students then attempted a few more on their own. Analysis of observational notes shows that Chloe did most of the talking, and students followed the procedure she presented to use the communicative property. All talk was student-teacher and focused on the correct answer. SMP7 was the only mathematical practice used, as Chloe wanted students to use the structure of “turnaround facts” in addition. On the MCOP², Chloe’s mean score was 0.8, which supports the idea that she was using traditional teaching methods (See Table 4.3).

**Second Observation- Chloe.** Chloe’s second observation, mid-Phase One PD, lasted 23 minutes and focused on solving number stories. During the observation, students worked independently to solve an addition number story and then shared how they solved it. Chloe presented the mathematics problem and asked students, “What is the problem about?” and “What information is
important? Students used cubes and whiteboards to solve the problem. They were encouraged to “figure it out in your own way.” After a short work time, a student was selected to share his work with the group. This student shared his answer and what he did to find the answer. Students were asked if they agreed or disagreed with the work and if anyone “solved it a different way.” One of these students was invited to share their work. Again, students were asked if they agreed or disagreed with the work. As the observation concluded, students were given a new number story to solve. Analysis of observational notes indicates that students were given the opportunity to practice SMP3. Five students were asked to present their mathematical thinking and then allowed to show if they agreed or disagreed with that student. The lesson focused on getting the right answer, but Chloe wanted her students to “listen to each other” and “think about what they did.” Allowing students to “solve it their own way” supported the development of SMP5, as students could use the tools provided in multiple ways. On the MCOP2, Chloe’s mean score was 1.3, indicating that she has added some conceptual practices to her teaching. (See Table 4.3)

**Third Observation-Chloe.** Chloe’s third observation post-Phase One PD lasted 27 minutes. The lesson focused on solving subtraction number stories. Students were presented with a problem and asked to “figure it out for yourself.” Most students used counters, while a few used number sentences or pictures to find the answer. Chloe allowed students to share their work with the class and then asked prompting questions to help them explain their answers. Three problems were solved during the lesson, with varying levels of success from the
students. Analysis of observational data indicates that Chloe’s practices continue to focus on SMP 3 & 5 as students were encouraged to use multiple ways of representing their work and practice explaining their thinking. This choice supported all students in engaging in the lesson and sharing their thinking.

*Table 4.3 Observational Data of Chloe’s Phase 1 Observations*

<table>
<thead>
<tr>
<th>MCOP² Practice</th>
<th>Obs. 1</th>
<th>Obs. 2</th>
<th>Obs. 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students were engaged in mathematical activities.</td>
<td>2</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Students critically assessed mathematical strategies.</td>
<td>0</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>The lesson involved fundamental concepts of the subject in promoting relational/conceptual understanding.</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>The lesson included tasks with multiple paths to a solution or multiple solutions.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>The teacher’s talk encouraged student thinking.</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>There was a high proportion of students talking related to mathematics.</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>There was a climate of respect for what others had to say.</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>In general, the teacher provided wait time.</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Students were involved in communicating their ideas to others (peer to peer).</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>The teacher uses student questions/comments to enhance conceptual mathematical understanding.</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

| Mean Score (Score of 3 is proficient)                                            | 0.8    | 1.3    | 2.1    |

*See complete data in Appendix H.*
Giving students more time to think supported their development of SMP1, making sense of problems and persevering in solving them. While the focus was still on getting the right answer, students were given the time to try different strategies to solve the problems. All discourse continued to be student-teacher as all responses went through Chloe. She asked questions, and the students responded to her. Student responses focused on explaining how they got the correct answer. On the MCOP², Chloe’s mean score was 2.1, indicating she continues to shift towards conceptual teaching practices (See Table 4.3).

**Phase Two – PD Observations.** A Community of Practice (CoP) model for PD changed the focus of Phase Two observations. Observations in this phase were used as a form of learning and reflection (Olanoff et al., 2021). They were also used as a data collection tool on the use of discourse strategies. Participants selected lessons with effective discourse or showed a change in their teaching practices related to the CoP focus from PD. The observations were not for data collection alone but for reflection, learning, and improving practice.

**Fourth Observation- Donna.** The lesson for Donna’s fourth observation occurred before Phase Two PD and focused on strategies for adding. The observation lasted 27 minutes. Donna had a new class of students who did not use much discourse last year. In this lesson, students used “Popit” bracelets to practice addition facts. The lesson included four opportunities for students to “talk with each other” about the mathematics problems they were working on. They would share the fact they made on their bracelet. Donna then shared the lesson’s number stories on the board. Students used their bracelets to solve the problems
and write the number sentence in their books. Donna called on students to share their answers and walked around to ensure that all students had the correct sentence written in their books. As the observation ended, students were working independently on number stories.

Analysis of observational data showed that SMP5 & 5 were a focus of this lesson as students used the “Popits” to model the mathematical expression, which increased student engagement. Donna added discourse to her teaching practices asking students to compare their answers with each other; however, students were given a very short think time, and the focus was on the correct answer. Donna selected two students to share their work, ensuring those who shared had the right answer. On the MCOP², out of 10 items, Donna’s mean score was 1.9. This score was lower than observation 3. Donna shared that this was because she “needed to teach routines” as it was the beginning of the school year. (See Table 4.4).

**Fifth Observation- Donna.** Mid-Phase Two PD Donna implemented a partner activity in this review lesson instead of following the curriculum’s directions. In this 23-minute observation, students used 10-frames to solve mathematics problems using the “make a ten” strategy. After giving initial directions, students worked with cubes to solve problems and explain their thinking. Donna walked around assisting students and asking questions. She worked to ensure all students wrote their work down correctly. When Donna noticed several groups missing a step, she gathered their attention to review the steps. She then went to a struggling group to support and encourage them.
Analysis of observational notes showed a notable change in Donna’s teaching practices. This review lesson allowed students to practice SMP 1, 3, 4, 5, and 6. Students worked with a partner to practice and apply the “make a ten” structure to different addition problems. In this lesson, observational notes state, “Donna was the facilitator and supporter instead of the teacher in the front of the room.” Donna encouraged explanations and supported student misconceptions. All Students were engaged in the lesson as they worked with their partners to explain their thinking and help with misconceptions. Students were given ample time to think and process as the focus was on using the strategy correctly, not on how many problems were answered. On the MCOP², Donna’s mean score was 2.5, with her most notable traditional practice being the requirement to follow the correct steps to get the answer. (See Table 4.4).

**Sixth Observation- Donna.** Subtraction number stories were the focus of Donna’s sixth observation. In this 20-minute session, students worked with a partner to solve numbers stories. They were encouraged to try different strategies and compare them with their partner. Donna asked questions and encouraged students to explain their thinking and work. All students were working and sharing their thinking with each other. Analysis of observation notes shows that SMP 5 was added as a focus of Donna’s teaching practices. Donna no longer expected her students to use the strategy she wanted but asked them to “use the strategy that works for them.” Students used multiple strategies to solve the mathematics problems and worked to explain their thinking to their partners.
Table 4.4 Observational Data of Donna’s Phase 2 Observations

<table>
<thead>
<tr>
<th>MCOP² Practice</th>
<th>Obs. 4</th>
<th>Obs. 5</th>
<th>Obs. 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students were engaged in mathematical activities.</td>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Students critically assessed mathematical strategies.</td>
<td>2</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>The lesson involved fundamental concepts of the subject in promoting relational/conceptual understanding.</td>
<td>2</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>The lesson included tasks with multiple paths to a solution or multiple solutions.</td>
<td>1</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>The teacher’s talk encouraged student thinking.</td>
<td>2</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>There was a high proportion of students talking related to mathematics.</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>There was a climate of respect for what others had to say.</td>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>In general, the teacher provided wait time.</td>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Students were involved in communicating their ideas to others (peer to peer).</td>
<td>1</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>The teacher uses student questions/comments to enhance conceptual mathematical understanding.</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

| Mean Score (Score of 3 is proficient)                                                                                                                                                                                                                                                                                                            | 1.9   | 2.5   | 2.8   |

*See complete data in Appendix H.*

On the MCOP², Donna’s mean score was 2.8, indicating that most of her teaching practices are conceptually based. Donna scored lowest on her range of higher-level questioning (2) and encouraging students to ask questions of each other instead of relying on her to ask them (2). (See Table 4.4)

**Fourth Observation- Chloe.** Chloe chose “daily data” for the pre-Phase Two PD observation. She stated that this observation time was selected as it was
when her students were “most able to share their mathematical thinking.” Daily data is part of Chloe’s morning routine when students review mathematics skills they have been practicing. Most days, there are two to four questions for students to complete. The focus of this 10-minute mini-lesson was on making 10 to add. With no lesson plan for this activity, Chloe chose problems that her students struggled to understand. After completing the problems, students came to the front and shared their work with a partner while waiting for other students to finish. Students were encouraged to share their work. Chloe guided the sharing, selecting students to share their work. Four students were selected; two had the correct answer but did not use the correct strategy. Chloe supported those students in using the correct strategy. The two students who used the correct strategy shared their thinking. Analysis of observational notes shows a focus on SMP 1, 6, and 7. Students were given time to make sense of the problems, and Chloe encouraged students to use the structure of the making a ten strategy to find the answer. Chloe used questioning strategies to support students to be precise in their explanations. She was looking for the answer and how students could explain their thinking to others. On the MCOP², Chloe’s mean score was 2.0, indicating a split between traditional and conceptual practices (see Table 4.5). All discourse continues to be student-teacher, Chloe’s most significant traditional practice.

**Fifth observation- Chloe.** The Mid-Phase Two PD observation focused on data as part of a Ready Mathematics lesson (Curriculum Associates LLC, 2020). In this 22-minute observation, Chloe presented several problems to the
class. Students worked independently to solve the problems, shared their strategies with a partner, and then the volunteers shared with the class. Students went to the board to share his/her work, and classmates agreed or disagreed with their strategy. When one student struggled to model his strategy, Chloe had another student come up and support his peer in determining the answer. Analysis of observational notes shows a shift in practices to include SMP 3. The student-student discourse was added into her routine to allow students to share their thinking. When a student had a misconception, Chloe asked another student to explain their reasoning instead of explaining herself. She also asked the class to evaluate different strategies to determine which might be more appropriate. On the MCOP², Chloe’s mean score was 2.5 showing an increased use of conceptual practices. With the whole group discussion, Chloe still directs the discussion and guides students toward the correct answer (see Table 4.5).

**Sixth Observation- Chloe.** Chloe’s sixth lesson focused on understanding and using the number grid. In this 24-minute observation, Chloe projected the hundred number grid on the board, and students were tasked with filling in the missing spots and sharing how they determined their answers. Chloe prompted students on whether they agreed and then asked for further explanations on how they knew which number to write. When students struggled with their answers, Chloe asked her students to help. Students then talked with their weekly partners and used the number grid to determine number patterns. Students moved on to independent practice as the observation ended. Analysis of the observational data shows an increased focus on SMP 2, 4, 5, and 6. Students were
encouraged to “look for patterns” on the number grid and apply them to find the
missing number. When one student struggled to explain their thinking, Chloe
asked a second child to help. When this second child also struggled with their
explanation, Chloe used a number grid to model the mathematical idea, asking
questions to develop their thinking. On the MCOP², Chloe’s mean score was 2.9,
indicating a proficient use of conceptual teaching practices. (See Table 4.5).

Table 4.5 Observational Data of Chloe’s Phase-two Observations

<table>
<thead>
<tr>
<th>MCOP² Practice</th>
<th>Obs. 4</th>
<th>Obs. 5</th>
<th>Obs. 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students were engaged in mathematical activities.</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Students critically assessed mathematical strategies.</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>The lesson involved fundamental concepts of the subject in promoting relational/conceptual understanding.</td>
<td>2</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>The lesson included tasks with multiple paths to a solution or multiple solutions.</td>
<td>1</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>The teacher’s talk encouraged student thinking.</td>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>There was a high proportion of students talking related to mathematics.</td>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>There was a climate of respect for what others had to say.</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>In general, the teacher provided wait time.</td>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Students were involved in communicating their ideas to others (peer to peer).</td>
<td>1</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>The teacher uses student questions/comments to enhance conceptual mathematical understanding.</td>
<td>2</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

| Mean Score (Score of 3 is proficient)                                           | 2.0    | 2.5    | 2.9    |

*See complete data in Appendix H.*
**Data Collection Summary – Mathematics Classroom Observation Protocol**

The Mathematics Classroom Observation Protocol (MCOP², Gleason, 2015) was used to collect data on teaching practices to answer RQ1, *How do elementary teachers’ mathematical teaching practices change after receiving situated, ongoing professional development focused on using productive discourse in the classroom?* Quantitative data showed that both participants shifted towards more conceptual practices. Donna’s scores went from 0.7 to 2.0 in Phase One and 1.9 to 2.8 in Phase Two for a change of 2.1. Chloe’s scores went from 0.8 to 2.1 in Phase One and 2.0 to 2.9 in Phase Two for a change of 2.1. Data showed that the two-phased PD resulted in positive changes in teaching practices. (See Figure 4.2) Appendix H shows the complete data.

![Figure 4.2 – MCOP² Summary Data](image)
Standards-based Teaching Practices (SBTP, Ross et al. 2003)

Data Collection Results

**Pre-assessment.** Participants completed the SBTP before any professional development. Pre-SBTP was used to determine baseline data to show changes in conceptual teaching practices. Results of the Pre-SBTP were used as a formative assessment to guide the initial PD. Grounded in Vygotsky’s Zone of Proximal Development (ZPD), it was necessary to start where teachers currently were and then support them in changing their teaching practices (Shabani, 2016; Vygotsky, 1978).

Pre-SBTP Data showed a range of responses for both participants, some conceptual and some traditional, but most somewhere in the middle. Donna ranked three of her practices conceptually, stating that students should work together, feel like they can do mathematics, and see mathematics as useful. Donna ranked none of her practices as traditional. In most practices, Donna ranked in the middle of the spectrum. Donna’s mean score was 3.25. Chloe ranked her practices conceptually on six different questions stating that she believes all students should think they can do mathematics, work collaboratively and use manipulatives. The focus should not be on the right answer. She ranked number 12 very traditionally, stating that students should master basic facts before working on complex problems. The other thirteen questions ranged in the middle. Chloe’s mean score was 3.55 / 5. (See Appendix 9).

**Mid-PD Assessment.** The SBTP was completed again at the end of Phase-One PD to determine any changes in teaching beliefs. Data showed
changes in both teachers’ practices, indicating an overall trend toward more conceptual practices. Donna ranked five practices conceptually, one practice traditionally, and fourteen in the middle of the spectrum. In this second survey, Donna ranked number 12; creating rubrics for math is a worthwhile assessment strategy, lower than the pre-assessment indicating a shift back to more traditional practices. She said, “Rubrics just take too much time.” The two practices she shifted to conceptual were students working together and using manipulatives. Donna’s mean score was 3.4/5. Chloe ranked twelve practices conceptually, zero practices traditionally, and six in the middle of the spectrum. Chloe’s shift towards conceptual practices included the idea that problems can be solved in multiple ways, some that she has not thought of, students need to learn about data and facts, and she teaches her students to explain ideas. Chloe’s mean score was 4.4/5.

**Post-PD Assessment.** The SBTP was completed again at the end of the Phase-two PD session to determine any further changes in teaching practices. Data showed that both teachers continued shifts to conceptual mathematical teaching practices. Donna ranked eight practices conceptually, one practice traditionally, and eleven in the middle of the range. Key practices of change were shifting the emphasis from the correct answer to the process, solving problems in multiple ways, and she teaches students to explain their mathematical ideas. Donna’s mean score was 3.95/5. Chloe ranked sixteen practices conceptually, zero practices traditionally, and four in the middle of the range. Key shifts were in giving students real-life problems; integrating assessment into mathematics.
activities and using calculators will not prevent learning mathematics skills.

Chloe’s mean score was 4.70 / 5. Appendix H shows the complete responses.

**Data Summary**

The Standards-based Teaching Practices (SBTP, Ross et al. 2003) were used to collect data on teaching practices to answer RQ1, *How do elementary teachers’ mathematical teaching practices change after receiving situated, ongoing professional development focused on using productive discourse in the classroom?* Qualitative data shows that both participants believed their teaching used more conceptual-based teaching practices. On a scale of 1-5, Donna’s practices shifted from 3.25 to 3.95, showing a slight shift toward conceptual teaching practices. Chloe’s practices shifted from 3.55 to 4.7, indicating a more notable change. This data suggests that the two-phased PD shifted teaching practices to be more conceptually based.

**Individual Teacher Interview Protocol**

**Data Coding Procedure.** A three-cycle, Inductive coding process was used to find the themes from participant interviews (Williams & Moser, 2019). Each interview was video recorded and added more details allowing the researcher to access the interview during coding. In the first cycle, open coding was used to find key terms and ideas from participants’ perspectives. Key words and phrases were recorded from each interview onto a spreadsheet. In the second cycle, the researcher printed and organized the open codes into groups to find critical patterns within those ideas and perspectives. Once the patterns emerged, a third round of coding occurred. In this last cycle, selective coding was
used to organize the patterns into the key themes found within the interview. A separate three-cycle coding process was completed for each phase independently to determine changes after each phase of PD. Table 4.6 shows the coding for Theme One. Other theme coding can be found in Appendix I.

*Table 4.6 Phase One Coding for Theme 1*

<table>
<thead>
<tr>
<th></th>
<th>Pre-PD get through the lesson</th>
<th>Mid-PD Teaching What to do</th>
<th>Post-PD Supporting Understanding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Follow teacher's guide</td>
<td>know what to do</td>
<td>Understanding why it is correct</td>
<td></td>
</tr>
<tr>
<td>Go through the pages</td>
<td>Students know the steps to follow</td>
<td>They need to see to understand</td>
<td></td>
</tr>
<tr>
<td>What Ready says</td>
<td>Showing them the right way</td>
<td>Know which strategy</td>
<td></td>
</tr>
<tr>
<td>Follow lesson plans</td>
<td>Explain what to do</td>
<td>They need to know why an inch is more</td>
<td></td>
</tr>
<tr>
<td>Make sure they get it</td>
<td>Help figure out the answer</td>
<td>There are different ways to do it</td>
<td></td>
</tr>
<tr>
<td>Do each step</td>
<td>Do fact families</td>
<td>Make sure they all understand</td>
<td></td>
</tr>
<tr>
<td>Get the right answer</td>
<td>Know the rules</td>
<td>Many ways to solve it</td>
<td></td>
</tr>
<tr>
<td>Show students what to do</td>
<td>procedures</td>
<td>Explain their ideas</td>
<td></td>
</tr>
<tr>
<td>Finish the pages</td>
<td></td>
<td>Understand how to solve to get the right answer</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Know why it is right</td>
<td></td>
</tr>
</tbody>
</table>

*Phase One*

Phase One coding began with open coding from observations, teacher interviews, and informal conversations between each observation. Key words and phrases were recorded in a spreadsheet. After the open coding was
completed, data was organized into patterns. Patterns from all Phase-One interviews were then compiled and organized using selective coding to determine overall themes. Phase One of the PD process had three critical themes emerge through interviews and informal conversations (see Figure 4.3). Participants’ responses focused on their teaching practices, student discourse, and the changes in their teaching practices. For complete coding results, see Appendix I.

**Theme one: Teacher Role in Mathematics Teaching**

*Pre-PD Pattern: Get through the lesson.* Both teachers verbally stressed unease before their first observation. The new curriculum and students made them very uncomfortable with the lesson. The *Ready Mathematics Curriculum* (Curriculum Associates LLC., 2020) has a different teaching format from previous curriculums. Chloe shared that she was “trying to follow the teacher’s guide” and ensure “we got through all the pages.” Donna stated, "This is so different from what I used to do.” New to second grade, she shared, “I don’t know what they learned last year, so I need to make sure they can do the work.” While discourse is a vital part of the lesson plans, there was a fear that students would not learn what they needed if the teachers did not control the discussion. As Chloe stated, “I need to make sure we follow the lesson plans,” and Donna said, “I need to make sure the students get the lesson.” Both teachers shared that they do not know about discourse, so they are “doing what they are comfortable with” and ensuring students “finish the pages.”
Mid-PD Pattern: Teaching what to do. The second interview was conducted after the second observation. It showed that both teachers had shifted their roles from teaching the lesson to ensuring the students' understood what to do at the end of the lesson. In her lesson, Donna shared that she wanted her students to be able to do fact families because that would “help her kids when the focus moves to subtraction number stories.” She said she was working to “help students learn to explain what they did, ” which was her “goal of the discourse.” She repeated what they said to “make sure everyone heard it.” Ultimately, she wanted to ensure they all could do fact families “correctly.”

Chloe thought this lesson was a “big change in teaching” for her. She was trying to “ask questions and help explain their thinking.” Her goal was not to answer the questions but help “kids figure out the answer.” She was proud that
she encouraged students to “figure it out in their own way.” Chloe explained her reasoning, and she reviewed the problem at the end. She needed to ensure they all “knew what to do.”

**Post-PD Pattern: Supporting Understanding.** In the third interview and informal conversations after the PD session, both teachers shared that they wanted their students to develop mathematical understanding instead of focusing on the process. With increased story problems at this point of the year, they found their students not knowing “what to do to solve the problem.” Chloe shared that discourse has helped her students “be more solid” with mathematics but struggle to “know which strategy will work.” Donna said her students are good at noticing “they have different answers, but they don’t understand why they did.”

Donna shared that her students had been struggling with the comparison units of measurement in previous lessons. Her lesson was more teacher-directed because she wanted to ensure students understood the “right answer” and “why it was correct.” As the students were in their group discussions, she noticed many “wrong answers.” These wrong answers concerned her because they need to “know how to do it.” She allowed students to “share their thinking” to ensure “they all heard it and could understand.” These comments contradict her statement that her focus was on mathematical understanding. It was more about understanding what to do than understanding the mathematical concept.

Chloe said she significantly shifted her role by moving from the front of the classroom. When the students shared during this lesson, she moved and “sat with the kids.” She did this to help “keep the kids paying attention” and put them
“in charge of showing their work.” Chloe wanted the students to “explain their ideas.” She also stated she succeeded in “selecting and sequencing the students she wanted to share.” It was important to Chloe that they showed “different strategies to solve the problem.” At the end of the lesson, she reviewed the strategies to ensure “everyone understood ways they could solve it.”

Both teachers stressed the importance of student understanding but focused on understanding so students could get the right answer.

**Theme two: Student Discourse**

**Pre-PD Pattern: Struggle.** Both teachers shared that student participation was a struggle in their lessons. They stated that they felt students were off-task for portions of the lesson. Chloe shared, “You know my class; they are a challenge; they just want to play with the blocks or talk.” Students were moving around throughout the lesson. Donna stated, “My kids had a hard time paying attention. They know how to read graphs, so I was just trying to finish the lesson.” Supporting student discussion was a challenge shared by both teachers. When given a chance to talk, both teachers stated that they felt students tended to share their answers but did not know how to continue. Chloe stated, “Students would share their answers and then just play with the blocks. They do not know what else to say, so I want to show them what to do.” Donna stated, “When my students share, they just give the answer and say they did it in their head. They can’t explain it, so I explain it for them.”

**Mid-PD Pattern: Increased Participation.** Both teachers shared that they were excited about the change in student participation in their lessons. Donna
shared that she was proud of allowing students to come up with their own fact families after being given only two numbers. She shared that her students knew to “switch the numbers to write all the equations.” This was a “strategy she learned in school.” She noted that she had increased student participation by allowing students to “come up and write the equation.” Donna also shared how the students could use hand signals to show they “agreed or disagreed with their friends.” Knowing if the answer was correct was important because she knew if “the answer was correct or not.”

Chloe shared that her biggest concern was the behavior of her students. She did not feel she could give much extra time or have too much talking because several of her students cannot stay focused and “start bothering others,” and they “do not listen to each other.” Despite these concerns, Chloe had two students share their work in this lesson. Afterward, classmates would give a hand signal if they “agreed or disagreed” with the answer. Chloe was proud of how they could “talk about what they did” and “explain their thinking.” She was also pleased that most of them could get the correct answer. At one point, a student asked a question, and she asked the other students if they could answer it. Chloe indicated this was a big step since she did not answer the question herself. “I am asking more questions and then give them time to grapple - not just spoon-feed them.”

Post-PD Pattern: Guided Mathematics Talk. Both teachers expressed pride that their students did “more talking” during the mathematics lessons. They felt their students were “sharing their ideas” and “explaining their thinking.”
Donna stated that small groups were essential because “everyone gets a chance to talk in a short time.” She shared that her shortened mathematics time due to being an immersion teacher continues to be an issue for her. She figures this is a way to “let everyone share” and encourage students to “try to find the answer.” She was proud that “I am letting them do more of the teaching. They come up and explain instead of me doing it.” Chloe felt her students did “most of the explaining” in the lesson. She communicated that she felt it was her job to “do the teaching.” Her students could now “explain how they got their answers.” Chloe noticed times “when one kid shares a way they think and the next problem someone else tries and sees if they can do it that way.” She was proud of how well they could share their ideas.

**Theme Three: Changes in Practice**

**Pre-PD Pattern: Current practices.** Since PD had yet to begin, this interview focused on their teaching practices. Teachers shared what they thought was important about teaching math. Chloe stated that she needs to “do what is in the teachers’ guide,” that is, the curriculum and “what I am supposed to teach.” On the other hand, Donna shared that it was important for students to “get the right answer.” She felt her job was to “make sure the students know what to do.”

**Mid-PD Pattern: Making some changes.** Donna stated that her teaching practices had “improved” since the year began. She indicated that her students “knew what to do” so she could give them “more time to talk instead of me talking.” The observation lesson was the first in the session, and she stated she did more direct teaching in this one so that the “students would know what to do.”
Donna also shared that the next day, students were allowed to roll dice, write their equations in groups, and share the facts families with a partner. She was encouraged by how “the kids talked about math as they did their work.” She set a goal to “add student discussion before I show them on the board” in upcoming lessons. In an informal conversation, Donna shared that her students were “doing more talking because it is making more sense to them.”

Chloe stated that this lesson was “a big change from the way I used to teach.” She stated she” feels more comfortable with the curriculum,” and the PD “gives her ideas to improve it.” She shared that she has connected with Smith and Stein’s (2018) idea of students sharing multiple strategies to build conceptual understanding, which was the focus of changes in her teaching practice. Chloe set a goal to try and have her students talk to each other, but she shared that she is worried that they will “not talk about math” or stray from what the “book wants us to do.”

**Post-PD Pattern: Sharing and Explaining.** Donna was very proud of how well her students were talking and sharing. She stated that her students were “better at explaining their thinking.” She attributed it to “getting to talk in small groups.” She shared that she tried to give them multiple chances each day to “talk about math” and encouraged them to “explain their thinking to their friends.” She shared a different teaching time when students were “arguing” about an answer and how proud she was that they were using “math to explain what they did.” After discussing the limited time her students were talking during
the lesson, Donna set a goal of increasing her student talking time so they had more time to “share their ideas.”

Chloe’s third interview shed new light on her teaching practices and struggles with implementation. She left the interview with a different view of her teaching. As we talked, Chloe shared her frustrations that the discourse was not going as well as she had hoped. She has a tough group and does not think they listen to her, much less each other. Then Chloe shared that she has a separate mathematics time, “daily data,” a review of critical concepts. She shared that the students lead the discussions and sharing at this time of the day. Students come up and share what they are thinking and guide the direction of the ideas. After further probing, she shared that she could allow students the time here because “there wasn’t a curriculum to follow.” When it was shared that she should celebrate this because, at the beginning of the year, there was no way she would have allowed this open sharing, it took her by surprise, but she agreed. She had not thought of it that way and was very proud of herself. She set a goal to try that same discourse in a mathematics lesson and not worry about “getting through the lesson.”

**Phase Two**

Phase Two data was compiled using the same three-cycle, inductive coding process (Williams & Moser, 2019). The timing was the main difference as each interview was coded after the interview instead of coding them all at the end, allowing the researcher to modify the PD based on the interview data. Two different themes emerged during the second phase of the PD process. Being
more comfortable with the curriculum and discourse, interviews, PD discussions, and informal conversations with participants led to new themes. Figure 4.4 shows the process and summarizes themes.

**Interview Coding Patterns and Themes**

**Phase 2**

**Figure 4.4: Coding Patterns and Themes - Phase Two**

**Theme One: Mathematical Goals.** The main focus of Phase Two of PD was discourse, so most PD sessions were spent discussing and setting individual discourse goals and improving the use of discourse in their teaching practices.

**Pre-PD Pattern: Setting Up Routines.** The start of Phase Two was the beginning of a new school year. Chloe and Donna stated that setting up classroom routines and teaching their students was significant. They wanted to set expectations and models for students who did not use discourse in their classroom the previous year. The need to set up routines shifted their teaching practices to be more teacher-directed, as the focus was on building routines for
the year. Chloe stated, “Last year, we didn’t start with discourse, and it is hard to change in the middle of a year. I want to set it up from the beginning.” Donna shared that “with this group, it will take time before they are ready to have good talk.” This need for developing a routine was evident in their first observations as both teachers guided most of the lesson. Donna had given students a new manipulative and wanted to ensure they used it as a mathematics tool. “It isn’t a toy, but a math tool.” Chloe was using her daily data time for her first observation. She guided students through the presentation and sharing of their work. “Can you explain what you did? How did you get that answer?” Chloe was modeling a routine to support student understanding.

**Mid-PD Pattern: Students Working Together.** A vital portion of the first half of the Community of Practice (CoP) was observing, modeling, and using discourse in the classroom. The goal for the second observation was a lesson where participants and students were using discourse. Both teachers had a notable increase in their use of discourse. Donna had shifted her practices and used *Ready Mathematics* (Curriculum Associates, 2020) “Refine” session as a peer review session. A Refine session is at the end of a lesson and is meant to support students independently refining their thinking of the topic. Donna made it a partner activity so “students can help each other” and “practice their explaining.” She shared that her students “can’t always explain their thinking,” which could mean “they might not understand.” As students worked in peer groups to use the “make a ten” strategy, Donna met with groups, supported their
explanations, and checked for misconceptions. Donna shared that this lesson “showed me who understood and who needed more help.”

Having taught the routine, Chloe’s class could now utilize their “weekly partner” to discuss their work. After independently solving the problem, students used peer discourse to discuss and explain their work and check for errors. Chloe listened to groups and supported students as needed. Next, Chloe called on students to come and share their work. She specifically chose a student who did not get the correct answer and then asked, “Who can help M?” A student came up and showed how he got the answer. Chloe used prompts like, “What did you do next?” and “Why did you do that?” to support his explanation. In her interview, Chloe shared that she has been working on selecting students who make mistakes because they “want to share too,” and it helps others to “work on their explanations.”

**Post-PD Pattern: Supporting Students.** Now that discourse was part of the classroom routine, the participants sought ways to improve their discourse. The final few sessions of PD focused on the quality of teacher-student interactions and the types of discourse students would use in the future. Donna and Chloe chose final lessons that allowed students opportunities for more dialogic interactions. Donna again had a lesson using peer discourse groups. This time, however, students discussed the strategy they used. Donna’s questions focused on students’ strategies and why they chose them. Donna shared, “There are so many different strategies they can use. They need to find the ones that work for them.” Students who finished early were encouraged to
“try a different strategy.” Donna wanted them to “try new ones to see if they could work.”

Chloe believed her final observation would be a “quick review of the number grid” but found out she was wrong. “They can write their numbers to 100, but they struggled to find a missing one.” These misconceptions led to better discourse with her students. Those who could determine the missing number had to explain their strategy. Chloe supported them with questions on how and why they knew it was correct. Chloe stated, “They had to talk about the number patterns.” She thought they explained it better because “they can use kid-friendly language” that other students understand.

**Theme two: What do I need?**

With a CoP, all participants have an active role in the PD sessions. Their ideas and needs are critical factors in the plan. These needs were an essential part of our interviews and their learning path.

**Pre-PD Pattern: What does it look like?** In the original focus group interview and after the first observation, Chloe and Donna shared a concern that they did not know “what discourse is supposed to look like.” Donna stated that she was not sure how to “guide students.” Chloe said she would like to “see videos of what it should look like for first grade.” Donna agreed with Chloe that discourse was “something we need to use,” adding that she was “unsure how to do it with my students.”

**Mid-PD Pattern: Feedback.** For the first time, after the fifth observation, both Chloe and Donna stated they looked forward to the interview to receive
feedback on their observed lessons. Instead of the researcher asking all the questions, both participants wanted to ask questions and needed more information on “what to talk about” when meeting with small groups. Donna tended to focus on the “right answer” but knew there was more she could be doing. She was unsure how to respond to student work to “help them learn more.” Suggestions were given on effective feedback and asking better questions to scaffold student learning. Donna was thankful for the suggestions and expressed excitement to try new things.

Chloe wanted to know “what I am doing wrong.” Looking at the growth and changing of practices, the discussion focused on additional ways to support student learning instead of perceived mistakes. Chloe expressed concerns that some students “didn’t get the right answer, but they wanted to share.” It was suggested that they could share and have a different student support them in finding their misconception. It was also suggested that students ask each other questions instead of all coming from her. Chloe expressed thanks for the new ideas and “had a plan to try in the next lesson.”

**Post-PD Pattern: On My Own.** As the semester ended, both Chloe and Donna expressed a desire to end the CoP. While both stated that the PD was helpful, they stated they felt comfortable using discourse. Donna stated that her “teaching had changed,” and she “felt good about where I am.” She stated, “You are just down the hall if I need it.” She said she “uses discourse at different times in the day” and “my kids are really talking about what they know.” When asked if she thought discourse helped her students, Donna stated, “Yes. They need to
know how to explain it – then they know." She said it was “time to do this on my own.” She feels comfortable with the routine she has set for discourse, and that discourse was part of that routine: “My students have weekly partners we use all the time.” Donna shared that she was proud of how she can now anticipate many of their needs and how she has shifted to let them explain.

Chloe told me she was “ready to do this alone,” sharing that it was time to help the teacher next door. She felt comfortable with her mathematics time, “I follow the lessons, but they lead the talking.”, “They listen more to each other than they do to me.”

**Data Collection Summary**

Qualitative Data from individual interviews was used to answer the first research question: *How does teacher participation in discourse-focused professional development influence conceptual teaching practices?* Coding themes show both teachers shifting their focus from “getting through the lesson” and “student struggles” to “supporting students” and using discourse “on my own.” Donna shifted from being” in control of the lesson” and “finding the correct answer” to helping students find the “strategy that works for them” and using discourse at “different times of the day.” Chloe shifted from “following the [teachers’] guide” and making sure they know the “right answer” to independent “daily-data time” where her students can often “explain it better than I can.” These data suggest a notable change in teaching practices.
Research Question 1 Data Collection Summary

Data from three sources, MCOP², SBTP, and individual interviews, were compiled to answer the research question: How does teacher participation in discourse-focused professional development influence conceptual teaching practices? Data from all sources indicate a change in teaching practices for both participants. (See Figure 4.5)

![Figure 4.5 Summary of Research Question 1 Data](image)

Individual observations, surveys, and interviews showed traditional teaching practices before PD. Participants’ practices focused on following the teachers’ guide and ensuring students could get the right answer. Following the two-phase PD, conceptual-based and discourse routines are a regular part of participants’ teaching practices. Both teachers allow time for student discourse, allow multiple strategies for problem-solving, and encourage students to explain their thinking.
Research Question 2

Data from the MCOP, DIT, and discourse questionnaire were used to support the findings for the second research question: How does teacher participation in discourse-focused professional development influence student use of discourse during instruction?

Mathematics Classroom Observation Protocol for Practices (MCOP²)

Frequency data were collected on the student’s opportunity for peer discourse. Descriptive statistics were calculated for engagement (Table 4.7) and time allowed for student-student discourse (Table 4.8).

Opportunity for Discourse. After Phase One PD, Chloe increased the number of students participating in teacher-student whole-class discourse from 9.09% to 36.36% (see Table 4.8). There was no opportunity for student-student discourse in her lessons. These numbers changed in Phase Two, and by the final observation, all students were engaged in peer talk, and 80% used discourse with Chloe in whole class discussions. Time was a factor in Chloe’s inability to meet with all students. In Phase One, Donna’s number of students participating in teacher-student discourse increased and decreased during her lessons. Still, student-student discourse increased from 0% in the first to 100% in the final lesson (see Table 4.8). Her small group time allowed students to talk, but there was less time for teacher-student discourse. In Phase 2, Donna’s lesson planning changed to embrace mostly partner work, allowing all students to work with a partner and Donna time to meet with each group.
### Table 4.7 Percent of Students Engaged in Discourse

<table>
<thead>
<tr>
<th>Observation</th>
<th>Teacher- Student Discourse</th>
<th>Student- Student Discourse</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Chloe</td>
<td>Donna</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>P</td>
</tr>
<tr>
<td>1</td>
<td>2/22</td>
<td>9.09%</td>
</tr>
<tr>
<td>2</td>
<td>5/19</td>
<td>26.32%</td>
</tr>
<tr>
<td>3</td>
<td>8/22</td>
<td>36.36%</td>
</tr>
<tr>
<td>4</td>
<td>4/20</td>
<td>20.0%</td>
</tr>
<tr>
<td>5</td>
<td>9/18</td>
<td>50%</td>
</tr>
<tr>
<td>6</td>
<td>16/20</td>
<td>80.0%</td>
</tr>
<tr>
<td>Change</td>
<td>+70.91%</td>
<td>+66.66%</td>
</tr>
</tbody>
</table>

*N=number of students / total students present that day  P= percent*

**Time Spent with Discourse.** In Phase One, the amount of time spent on discourse increased for Chloe from 4 minutes of a 24-minute lesson (16%) to 10 minutes of a 27-minute lesson (37%) (see Table 4.9). In Phase Two, Chloe continued to increase the use of discourse in her lessons ending with 16 minutes of a 24-minute lesson (67%). In Phase One, Donna spent most of the time guiding the instruction with a slight increase in discourse time from 3 minutes in a 22-minute lesson (14%) to 6 minutes in a 30-minute lesson (20%). Phase Two dramatically increased from 7 minutes of a 25-minute lesson (28%) to 18 minutes of a 20-minute lesson (90%). After giving directions, Donna spent most of the lesson meeting with partners and supporting their learning.
Table 4.8 Amount of Lesson Time in Minutes Students Using Discourse

<table>
<thead>
<tr>
<th>Observations</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Chloe</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discourse Minutes</td>
<td>4</td>
<td>6</td>
<td>10</td>
<td>4</td>
<td>8</td>
<td>16</td>
</tr>
<tr>
<td>Total Minutes</td>
<td>24</td>
<td>23</td>
<td>27</td>
<td>10</td>
<td>22</td>
<td>24</td>
</tr>
<tr>
<td>Percent</td>
<td>16%</td>
<td>26%</td>
<td>37%</td>
<td>40%</td>
<td>36%</td>
<td>67%</td>
</tr>
<tr>
<td><strong>Donna</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discourse Minutes</td>
<td>3</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>20</td>
<td>18</td>
</tr>
<tr>
<td>Total Minutes</td>
<td>22</td>
<td>27</td>
<td>30</td>
<td>25</td>
<td>23</td>
<td>20</td>
</tr>
<tr>
<td>percent</td>
<td>14%</td>
<td>18%</td>
<td>20%</td>
<td>28%</td>
<td>87%</td>
<td>90%</td>
</tr>
</tbody>
</table>

**Data Collection Summary.** Observational data and notes were used to determine the opportunities given to students to use discourse during the mathematics lessons to answer research question two: *How does teacher participation in discourse-focused professional development influence student discourse during instruction?* Data was collected on the number of students who participated in discourse and the amount of time discourse was used in the lesson. Data showed that both increased after the two-phased PD. In Donna’s classroom, discourse went from 33.34% of the students and 14% of the lesson to 100% of the students and 90% of the lesson. In Chloe’s classroom, the use of discourse went from 0% of the students and 16% of the lesson to 100% of the students and 67% of the lesson. This data suggests that students were engaged in more discourse after the PD sessions.
Dialogic Inquiry Tool (DIT, Reznitskaya et al., 2012)

Data Collection Results. The DIT was used during the observations to classify the discourse interactions (Kathard, 2015). Interactions were ranked from monolithic to dialogic, with transitional as a middle rank (Reznitskaya et al., 2012). Descriptive statistics were gathered to describe the interactions of both teachers throughout the observed lessons. Comparative statistics were used to determine a change in interaction levels.

Phase One

Donna Observation One. Donna’s first observed lesson contained mostly monologic interactions where students answered questions from the teacher. All six indicators were monologic, with a few transitional questions. Donna led the lesson, telling students what to do, “You need to count them all,” and “Write the answer here.” Feedback was short and vague, “You did it.” and “That’s right.” Student responses were also monologic, short, and factual: “Three,” “I added.” and “I counted them all.” Only Donna’s questioning interactions had transitional qualities as students tried to explain their thinking. “How are the bar graph and number graph the same?” and “What does your graph show?” Donna was in control of the lesson. Any discourse was focused on answering her questions or getting the right answer. Students did not have the opportunity to explain their thinking or collaborate. Data are shown in Table 4.9.

Donna Observation Two. Donna’s second lesson contained a mixture of monologic (authority, feedback, and collaboration) and transitional (questioning, meta-level reflection, and explanation) indicators. Donna led the lesson,
reminding students what to do, but questions and responses included more explanation. Monologic interactions showed authority and gave minimal feedback. Examples include “Write the fact family,” “Nice job!” and “Make sure you write it down.” Donna’s questioning and meta-level reflections showed an attempt to make connections. “What do you know about fact families?”, “Do you agree or disagree?” and “How are your equations the same?”. Student responses included more explanation: “I knew it was right because they all have the same numbers.”, “I can just switch the numbers around.” and “I knew it was a turnaround.” Students did not connect with peer thinking. “I wrote a subtraction one.” and “I knew it was a turnaround.” Data is shown in Table 4.9.

Table 4.9 Observational Data of Donna’s Phase 1 Interactions

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Interaction Type</th>
<th>Obs. 1</th>
<th>Obs. 2</th>
<th>Obs. 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Authority</td>
<td>Teacher-student</td>
<td>Monologic</td>
<td>Monologic</td>
<td>Monologic</td>
</tr>
<tr>
<td>Questioning</td>
<td>Teacher-student</td>
<td>Monologic</td>
<td>Transitional</td>
<td>Transitional</td>
</tr>
<tr>
<td>Feedback</td>
<td>Teacher-student</td>
<td>Monologic</td>
<td>Monologic</td>
<td>Monologic</td>
</tr>
<tr>
<td>Metalevel Reflection / Connecting</td>
<td>Teacher-student</td>
<td>Monologic</td>
<td>Transitional</td>
<td>Transitional</td>
</tr>
<tr>
<td>Explanation</td>
<td>Student-student</td>
<td>Monologic</td>
<td>Transitional</td>
<td>Transitional</td>
</tr>
<tr>
<td>Collaboration</td>
<td>Student-student</td>
<td>Monologic</td>
<td>Monologic</td>
<td>Transitional</td>
</tr>
</tbody>
</table>

**Donna Observation Three.** Donna’s third lesson contained mostly transitional interactions, with some monolithic authority and feedback interactions. Donna asked students to collaborate, “Discuss with your partner.”,
justify their thinking, “Do you agree?” and connect ideas in their small group discussions, “Can you share what you talked about?” Students were able to explain their thinking, “Meters are bigger, so you need less of them.” and connect to others’ ideas, “I agree because centimeters are smaller.” Donna continues to use monological feedback with her students, “That’s a good answer” and “That is what I was looking for,” and controls the lesson, “Make sure you write it down.” and content, “You need to compare these two.” Data are shown in Table 4.9.

**Chloe Observation One.** Chloe’s first lesson contained mostly monologic interactions, as all interactions were directed by her and to her. She instructed students on what to do, “Use your cubes” and “Come and show us the pile of 3 and pile of 4.” Feedback was general, “You got it.” or focused on the correct answer, “Yes, we have nine.” Student explanations focused on their actions, “I put them together.” no connections were made between student responses. Most questioning was monologic, “What is this box called?” and “What should I write here?”, but she also included transitional questions as well, such as “How do I know which box it is?” and “What do we know about a total?”. Chloe’s interactions guided the students through the problems and the correct answer. Data are shown in Table 4.10.

**Chloe Observation Two.** Chloe’s second lesson contained monologic (authority, explanation, collaboration) and transitional interactions (questioning, feedback, connecting). Chloe continues to direct the instruction, “Let’s read the problem together.” and “Use your cubes to find the answer.” She is, however,
transitioning in most other interactions asking students to think about the problem, “What is important information?” and “Is there another way?” and connect their thinking, “ Raise your hand if you did the same thing.” and “ He subtracted – did anyone else do that?” The students continued to use monologic responses, “I got three.”, “There is more cheese.” and “I did 8-5.” Their responses were short and focused on their own answers. Chloe controls most interactions, but she supported students in extending their thinking. Data are shown in Table 4.10.

Table 4.10 Observational Data of Chloe’s Phase 1 Interactions

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Interaction Type</th>
<th>Obs. 1</th>
<th>Obs. 2</th>
<th>Obs. 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Authority</td>
<td>Teacher-student</td>
<td>Monologic</td>
<td>Monologic</td>
<td>Monologic</td>
</tr>
<tr>
<td>Questioning</td>
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<td>Feedback</td>
<td>Teacher-student</td>
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<tr>
<td>Metalevel Reflection / Connecting</td>
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<td>Transitional</td>
<td>Monologic Dialogic</td>
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<tr>
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<td>Student-student</td>
<td>Monologic</td>
<td>Monologic</td>
<td>Monologic</td>
</tr>
</tbody>
</table>

**Chloe Observation Three.** Chloe’s third lesson contained mostly transitional interactions. She continued to control the lesson with monologic authoritative interactions, “Read the problem with me.” and “Make your line in a row.”, her questioning, feedback, and reflection showed transitional and some dialogic interactions. When it came to problem-solving, Chloe asked transitional
questions to assist students in knowing what to do, “How do we find out which is fewer?” and “What numbers are important in this problem?”. She also gave feedback to support their explanations, “Where did you get that number?” and “Show me which way you are working.” Chloe’s desire for students to solve the problem “whatever way works for you” ignited some dialogic interactions and connections from Chloe, “C used subtraction – did anyone solve it a different way.” and “That’s a good question. Boys and girls, what do you think? Do we use addition or subtraction?” Chloe’s students also had more transitional interactions in their explaining, “She gives some away, so there will be 10.” but they relied a lot on their work to show their thinking instead of using their words. Their collaboration was still monologic, focusing on what they did instead of connecting to others, “I subtracted.” and “I wrote 15-8.” Data are shown in Table 4.10.

**Phase One Comparative Results.** Data showed that most classroom interactions moved from monologic to transitional and dialogic interactions. Both Donna and Chloe continued to control the lesson with monological authoritative interactions, but their questions and reflection moved to more transitional. Students in both classes were expanding their explanations to more transitional interactions. Donna’s students were able to collaborate and build on others’ thinking. Chloe’s students continued to focus on their own responses. These data showed more room for teacher growth and provided the basis for Phase Two of the PD plan. Table 4.11 shares the comparison.
Table 4.11- Comparison of Dialogic Teacher-Learner Interactions

<table>
<thead>
<tr>
<th></th>
<th>Donna</th>
<th></th>
<th></th>
<th></th>
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<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Monologic</td>
<td>Transitional</td>
<td>Dialogic</td>
<td>Monologic</td>
<td>Transitional</td>
<td>Dialogic</td>
<td>Monologic</td>
<td>Transitional</td>
</tr>
<tr>
<td><strong>Obs 1</strong></td>
<td>6</td>
<td>1</td>
<td>0</td>
<td>6</td>
<td>1</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Obs 2</strong></td>
<td>3</td>
<td>3</td>
<td>0</td>
<td>3</td>
<td>3</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Obs 3</strong></td>
<td>2</td>
<td>4</td>
<td>0</td>
<td>3</td>
<td>4</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Change</strong></td>
<td>-4</td>
<td>3</td>
<td>0</td>
<td>-3</td>
<td>3</td>
<td>1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Phase Two

**Donna Observation Four.** Donna’s fourth lesson contained mostly transitional interactions, but her authority and feedback shifted back to monological. Donna continued to direct the instruction, “Make sure you count your pops.” and focused on the answer, “You need to write the correct answer.”, but added some transitional, “Share what you did.” and “Talk with your partner about your answer.” Donna’s feedback returned to a focus on the correct answer, “Yes! That is the right answer.” and “That is what I was looking for.” Donna’s questions focused on connecting student ideas, “What did you do that was different?” and “Do you agree with your partner?”, which showed in their responses, “I did a turnaround too.” and “We both popped 8, but it was different.” Students continued to struggle to explain their thinking beyond the procedure, “I counted the down ones.” and “I have 7 up and 3 down.” but Donna supported them in developing their explanations, “What else can you tell me?” and “How did you know that?”. Data are shown in Table 4.12.
**Donna Observation Five.** Donna’s fifth lesson showed shifts toward dialogic interactions (authority, explanation) while maintaining transitional in others (questioning, feedback, connecting, and explaining). Donna still uses some monologic feedback focusing on the specific procedure students should use: "Remember you need to write the tens problem." She also expanded to some transitional feedback, “So, how about we try building it?” and “What do you need to do first?” Throughout the observation, Donna walked around supporting their peer work and asked them to share their thoughts, “Make sure you are discussing with your partner what you did.” She also questioned them to explain further, “What did you do here?” and connect their thinking, “Do you agree with your partner?” Students used dialogic interactions with each other to explain their thinking, “We just realized it was 4 instead of 8, so we fixed it.” and “These are the 10; those are the extras on the bottom.” Student collaboration began to connect with each other,

Student 1- “9 + 2=11”

Student 2- And 10+1 = 11”

S3/S4 = “They are both 11! We got the same answer in a different way.”

While the end goal was for students to learn a procedure, Donna used more transitional and dialogic interactions to support student learning. Data is shown in Table 4.1.

**Donna Observation Six.** In her sixth lesson, Donna’s interactions with her students shifted to mostly transitional (feedback, connecting, collaboration) and dialogic (authority, questioning, explanation). In this lesson, Students worked with
a partner to find different strategies to solve the subtraction problems and then compared them. They used dialogic interactions to explain their thinking, “I counted with my fingers, but then I wanted to do something different.” and “It’s a number cross – that is what I call it.” Their connection interactions were more transitional, “I didn’t do that – I added a zero.” and “I used a number bond.” As Donna met with groups, she asked questions to extend their connections, “Do you agree with his answer and how he did it?” and “Maybe we need to think about where the 5 came from?” The interactions in this lesson shifted to supporting thinking and explaining mathematical understanding, “Explain to me.” and “It looks like your rainbows are going to multiple rainbows at the same time. Check your rainbows.” Data are shown in Table 4.12.

Table 4.12 Observational Data of Donna’s Phase 2 Interactions

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Interaction Type</th>
<th>Obs. 4</th>
<th>Obs. 5</th>
<th>Obs. 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Authority</td>
<td>Teacher-student</td>
<td>Monologic</td>
<td>Transitional</td>
<td>Dialogic</td>
</tr>
<tr>
<td>Questioning</td>
<td>Teacher-student</td>
<td>Transitional</td>
<td>Transitional</td>
<td>Dialogic</td>
</tr>
<tr>
<td>Feedback</td>
<td>Teacher-student</td>
<td>Monologic</td>
<td>Monologic</td>
<td>Transitional</td>
</tr>
<tr>
<td>Metalevel Reflection / Connecting</td>
<td>Teacher-student</td>
<td>Transitional</td>
<td>Transitional</td>
<td>Transitional</td>
</tr>
<tr>
<td>Explanation</td>
<td>Student-student</td>
<td>Transitional</td>
<td>Dialogic</td>
<td>Dialogic</td>
</tr>
<tr>
<td>Collaboration</td>
<td>Student-student</td>
<td>Monologic</td>
<td>Transitional</td>
<td>Transitional</td>
</tr>
</tbody>
</table>
**Chloe Observation Four.** Chloe’s fourth lesson showed mostly transitional interactions with a couple of monologic (authority, explanation) and a shift toward dialogic connections. Chloe continues to direct the lesson, “Take your counters and solve this problem.” and “Make your line in a row.” However, her questions, “Who can walk us through step by step?” and “What numbers are important in this problem?” and feedback “You don’t have 12 balloons yet. What do you need to do?” and “Show me which way you are working.” support the building of student mathematical understanding. Student’s explanations focus on what was done “There were 12.” and “She gives some away, so there will be 10.” While students discussed others’ work, “He didn’t start with the right number.” and “You didn’t jump.”, they didn’t compare their strategies. Data are shown in Table 4.13.

**Chloe Observation Five.** Chloe’s fifth lesson contained mostly transitional interactions, with Chloe, adding some dialogic interactions in connecting, “We need to infer what it means” and “That’s a good question. What do you think?” and explaining by students, “7-5=2 because 5+2=7”, and “We start with the 11 because it is bigger.”. Chloe directed the lessons through transition interactions, “You need to solve the problem and then talk to your partner and see if you agree.” but gave students time to work independently and discuss their thinking with their partners. Their collaboration was shifting towards transitional as they compared their strategies. Student interactions are more dialogic as they compare the strategies they use “I did the same thing and got 13.” and “We both counted back.” Data is shown in Table 4.13.
**Chloe Observation Six.** Chloe’s sixth lesson contained a mixture of transitional (authority, feedback, connecting, collaboration) and dialogic interactions (questioning, connecting, explanation). Chloe continued with transitional interactions in her guidance, “Can you explain how you got it?” and feedback, “Why do you disagree?” and “Can you explain to M what you did?” Her connecting interactions shifted towards dialogic with comments such as “Can you explain their strategy?” and “Do you understand how A got the answer?” Students continued with transitional collaborations, “Like he said, when you count by 10s, it is like counting by 1s.” and “I did the same thing. I looked at the 3.”. However, their explanations shifted towards dialogic, “You count to 100 by counting by 10s. I counted it 10 times.” and “After 6 is 7, so after 106 is 107.” they connected their responses to each other. Data are shown in Table 4.13.

**Table 4.13 Observational Data of Chloe’s Phase 2 Interactions**

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Interaction Type</th>
<th>Obs. 4</th>
<th>Obs. 5</th>
<th>Obs. 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Authority</td>
<td>Teacher-student</td>
<td>Monologic</td>
<td>Transitional</td>
<td>Transitional</td>
</tr>
<tr>
<td>Questioning</td>
<td>Teacher-student</td>
<td>Transitional</td>
<td>Transitional</td>
<td>Dialogic</td>
</tr>
<tr>
<td>Feedback</td>
<td>Teacher-student</td>
<td>Transitional</td>
<td>Transitional</td>
<td>Transitional</td>
</tr>
<tr>
<td>Metalevel Reflection /</td>
<td>Teacher-student</td>
<td>Transitional</td>
<td>Transitional</td>
<td>Dialogic</td>
</tr>
<tr>
<td>Connecting</td>
<td></td>
<td>Dialogic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Explanation</td>
<td>Student-student</td>
<td>Monologic</td>
<td>Transitional</td>
<td>Dialogic</td>
</tr>
<tr>
<td>Collaboration</td>
<td>Student-student</td>
<td>Transitional</td>
<td>Transitional</td>
<td>Transitional</td>
</tr>
</tbody>
</table>
Phase Two Comparative Results. Data showed that most classroom interactions moved from monologic to transitional and dialogic interactions. Before PD, Donna had six monologic, one transitional, and zero dialogic indicators. In her final observation, this changed to zero monologic, three transitional, and three dialogic indicators. Before PD, Chloe had six monologic, one transitional, and zero dialogic indicators. In her final observation, this changed to 0 monologic, three transitional, and three dialogic indicators. (See Figure 4.6) Complete data can be found in Appendix H.

![Figure 4.6: Comparison of Dialogic Teacher-Learner Interactions](image)

Discourse Questionnaire (Appendix C)

This data tool was completed by participants pre- and post-PD. This survey's purpose was to give teachers a voice in the impact of PD on their teaching. In the pre-survey, both teachers shared that they had no experience or knowledge of using discourse in their classrooms. On a Likert scale, both rated
their knowledge as a 1 out of 5. On their plans for using discourse, Donna stated she would “have more small group discussions,” and Chloe planned to do what “the teacher manual instructs me to.” Looking at PD needs, Chloe stated, “I do not know what I do not know.” Donna stated, “None.”

Phase 1 Post-PD surveys showed changes in their comfort with their knowledge, use, experiences, and implementation plan. Chloe changed her knowledge of discourse score from a one to a four on the Likert scale. She stated she was comfortable monitoring and selecting students but needed help anticipating their responses. She hopes that with practice and time with the new curriculum, she will become more proficient in anticipating student needs. Donna also changed her knowledge of discourse score, but only from a one to a two. She stated that she uses discourse daily and allows students to discuss their answers more in groups or on the board. Both said they did not know what other PD support they needed.

Phase 2 Post-PD surveys showed a further increase in their comfort with their knowledge and use of discourse. Both participants ranked their knowledge of discourse as a four out of five on the Likert scale and stated that they used discourse daily in their mathematics instruction. Chloe shared that discourse was part of her daily routine, allowing students to talk with a partner and then for a couple to share in front of the class. She shared that her students often “learn more from listening to their peers” as they “use the kid-friendly language they can understand.” Donna uses it as a way for students to develop their understanding. She now felt that “students know it better when they can explain it.”
Conclusion

In Phase One, both Chloe and Donna made changes toward more conceptual teaching practices. Still, neither would be considered proficient in conceptual based teaching practices based on observation (MCOP² and DIT) and survey (SBTP) data. While important, the changes did not provide students with the type of instruction needed to support conceptual mathematics learning. (See Table 4.14)

Table 4.14 – Changes in Practices after the Phase One of PD

<table>
<thead>
<tr>
<th></th>
<th>MCOP²</th>
<th>SBTP</th>
<th>DIT</th>
<th>T -S</th>
<th>S-S</th>
<th>Time using Discourse</th>
</tr>
</thead>
<tbody>
<tr>
<td>Donna</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-PD</td>
<td>.7</td>
<td>3.4</td>
<td>Monologic</td>
<td>33%</td>
<td>0%</td>
<td>14%</td>
</tr>
<tr>
<td>Post-PD</td>
<td>2.0</td>
<td>3.9</td>
<td>Monologic</td>
<td>25%</td>
<td>100%</td>
<td>20%</td>
</tr>
<tr>
<td>Chloe</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-PD</td>
<td>.8</td>
<td>3.55</td>
<td>Monologic</td>
<td>1%</td>
<td>0%</td>
<td>16%</td>
</tr>
<tr>
<td>Post-PD</td>
<td>2.1</td>
<td>4.4</td>
<td>Monologic</td>
<td>37%</td>
<td>0%</td>
<td>37%</td>
</tr>
<tr>
<td>Target for conceptual Teaching Practices</td>
<td>3.0</td>
<td>5.0</td>
<td>Dialogic</td>
<td>100%</td>
<td>100%</td>
<td>80%</td>
</tr>
</tbody>
</table>

Phase Two provided a new type of PD by introducing the CoP and focusing on discursive interactions. In this phase of PD, participants were more actively involved in their learning, giving suggestions to their peers and sharing ideas for what they needed. Both Chloe and Donna continued their growth
toward conceptual mathematics teaching. They both increased their use of conceptual discourse-based teaching practices and the opportunities for discourse they presented to their students.

Table 4.15 – Changes in Practices after Phase Two PD

<table>
<thead>
<tr>
<th></th>
<th>MCOP²</th>
<th>SBTP</th>
<th>DIT</th>
<th>Students Involved in Discourse</th>
<th>Time using Discourse</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>T-S</td>
<td>S-S</td>
</tr>
<tr>
<td>Donna</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-PD</td>
<td>.7</td>
<td>3.4</td>
<td>Monologic</td>
<td>33%</td>
<td>0%</td>
</tr>
<tr>
<td>Post-PD</td>
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</tr>
<tr>
<td>Chloe</td>
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<tr>
<td>Pre-PD</td>
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<tr>
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<tr>
<td>Target for conceptual Teaching Practices</td>
<td>3.0</td>
<td>5.0</td>
<td>Dialogic</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Chapter five details the holistic data analysis results, connections to prior research, and the theoretical framework and then describes a plan to use these findings to implement changes in PD in my district. The findings from this study could be transferable to other schools or districts to create PD support for teachers implementing conceptual mathematical practices.
Chapter 5 – Discussion

Overview of Study

This action research, exploratory, mixed-method case study investigated the impact of ongoing, contextualized professional development (PD) on teachers' practices and use of discourse in their classrooms. This iterative case study (Yin, 2018) focused on the changes in the teaching pedagogy of two teacher participants as they embarked on a journey of PD to improve their mathematics teaching practices. Two phases of PD, data collection and analysis, were used to document changes and develop a theory on the need for effective PD to implement conceptual and discourse-based teaching practices.

This mixed-methods case study used multiple data points to develop findings about the impact of PD on teaching practices and teacher beliefs. Quantitative data was collected using research-based observational forms, Mathematics Classroom Observation Protocol (MCOP)² adapted from Gleason (2015), the Dialogic Inquiry Tool (DIT) (Reznitskaya & Glina, 2018), and the Standards-Based Teaching Practices (SBTP) (Ross et al., 2004). Qualitative data was collected using questionnaires, semi-structured interview protocols, observational data, and informal conversations.

Chapter 5 summarizes and compares the findings from both phases, connects the findings to prior research, and discusses the study's limitations, recommendations for future practice, and implications for future research. It is
organized into eight sections (1) Answering research questions, (2) Discussion of Findings, (3) Theoretical Connections, (4) Goals of Action Research, (5) Professional Development Evaluation, (6) Limitations, (7) Implications for Practice, and (8) Summary.

**Research questions**

The following research questions were addressed in this mixed-methods case study:

1. How does teacher participation in discourse-focused professional development influence conceptual teaching practices?

2. How does teacher participation in discourse-focused professional development influence student use of discourse during instruction?

**Answering Research Questions**

**Research Question #1**

*How does teacher participation in discourse-focused professional development influence conceptual teaching practices?*

Data from the case study showed that ongoing professional development contextualized to the classroom can positively influence teaching practices. Both participants changed their mathematical instruction by adding conceptual teaching practices into their daily routines. Instead of focusing on the instructions from the teacher’s guide and students knowing the correct answer, both participants indicated that utilizing the Standards of Mathematical Practice (Appendix A) to develop understanding was equally important (CCSSM, 2010).
Teaching with SMPs gave students the opportunity to construct viable arguments, attend to precision while explaining, and critique the reasoning of others while solving and discussing mathematical tasks (Allenworth et al., 2021).

Donna’s shift to more conceptual mathematics embraced three key SMPs in her routine:

- SMP1. Make sense of problems and persevere in solving them
- SMP3. Construct viable arguments and critique the reasoning of others
- SMP 5: Use appropriate tools strategically

Using mathematics tools was the first SMP Donna embraced. She shared that mathematics tools “helps students see the math,” and they can “use them to show the problem.” Manipulatives can help students build meaning and connections (Kilpatrick et al., 2001). As she developed a deeper understanding of student mathematical thinking, Donna discovered the importance of making sense and preserving to problem solve (SMP1). She said she observed her students understanding mathematics more deeply when they grappled with the problem instead of following a prescribed one. Brandefur et al. (2021) had similar results showing that PD focused on building teacher understanding and allowing time for implementation. Reflection can result in changes to teaching practices which increase student understanding. The final SMP Donna embraced was constructing viable arguments and critiquing the reasoning of others. This was a challenge for Donna. She shared, “It was hard to give up control.” As Guskey (2003) stated, teachers need to see the positive impact on students before they
are willing to shift their teaching practices. The only negative Donna shared was the amount of professional learning time she spent on math. She felt there were other subjects she needed to focus on as well.

Chloe’s shift towards more conceptual practices surrounded 3 SMPs:

- SMP1: Make sense of problems and persevere in solving them
- SMP3. Construct viable arguments and critique the reasoning of others
- SMP6. Attend to precision

Making sense of problems and persevering, as well as constructing viable arguments and critiquing the reasoning of others, were the first two SMPs Chloe embraced as they were stressed in the *5 Practices for Orchestrating Productive Mathematics Discussions* (2nd ed.) (Smith & Stein, 2018). These five practices gave Chloe a structure to follow in her lessons, which was important for her teaching style. This connects with McGee, Polly, and Wang’s (2013) research that teachers will implement new instructional strategies based on knowledge acquired from PD and how they relate to their beliefs about teaching and learning. As Chloe supported her students in developing their ability to explain their thinking, SMP 6: attend to precision became relevant. In this case, it was precision in their explanations. She asked questions and supported students to explain what they did. “I counted” developed into “You count to 100 by counting by 10s. I counted it 10 times.” These results reflect those by Murata et al. (2017), showing that teachers’ support of students’ mathematics talk can support deeper mathematical understanding. The only negative impact Chloe shared was the
lack of time to collaborate with her new teaching partner. She felt like she was not able to support her as well as she wanted.

Connecting with the commognitive idea of routines to support mathematical learning (Sfard, 2007), both participants used mathematical routines to support their new instructional practices. Once students learned the routines, Donna and Chloe felt comfortable allowing them to lead discussions and develop their mathematical practices. Similar to Tabach and Nachlieli (2016), the development of routines gave students the structure they needed to focus on their thinking instead of the procedures they needed to follow.

This study adds to the research that ongoing PD contextualized to the classroom can positively impact conceptual teaching practices. When given effective PD, Teachers can develop new mathematical understandings and implement new practices to support student learning.

**Research Question #2**

*How does teacher participation in discourse-focused professional development influence student use of discourse during instruction?*

The findings from this holistic case study show that discourse-focused PD can positively impact student discourse. In this two-phased PD program, student opportunity for discourse dramatically increased in both classrooms and the level of discourse. Before PD, both Chloe and Donna led the whole group mathematics instruction. The discourse was monologic and teacher-student oriented, focusing on the right answer. Students were selected to answer questions focused on getting the right answer. Participants needed
contextualized, ongoing PD focused on developing an understanding of discourse, implementing discourse-based practices, and reflecting on their impact on student understanding to support a change in teaching practices (Gee & Whaley, 2016; Osana et al., 2011; Polly et al., 2015).

Current teaching practices for both teachers now allow multiple and varied student discourse opportunities. Donna’s lessons now focus on peer-to-peer discourse. Instead of one right answer, she believes, ”There are so many different strategies they can use. They need to find the ones that work for them.” Students are encouraged to work through problems together “so they can share their ideas” and create a learning environment where all students spend most of the lesson (85%) engaged in transitional and dialogic discourse. Chloe believes that students often explain things better as “they can use kid-friendly language” that other students understand. She uses students to support misconceptions instead of explaining them herself. Students lead the daily data portion of the day and have weekly partners to engage in transitional and dialogic discourse for a majority of the lesson (67%). (Mercer & Sams (2008) saw similar results: students’ mathematical thinking and explaining increases as teachers develop discursive teaching practices.

Findings from this study support the idea that contextualized, ongoing PD can positively improve students’ opportunities for productive discourse.

**Key Research Themes**

In this mixed methods study, holistic findings were derived from the triangulation of qualitative and quantitative data from both phases of the research
study (Tashakkori et al., 2020). Data was analyzed to find critical themes, takeaways, and connections to the literature presented in Chapter 2. Table 5.1 summarizes these themes.

Table 5.1 Key Findings Themes

<table>
<thead>
<tr>
<th>Theme</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theme 1</td>
<td>Discourse Makes a Difference</td>
</tr>
<tr>
<td>Theme 2</td>
<td>Going Beyond the Book</td>
</tr>
<tr>
<td>Theme 3</td>
<td>Defining Ongoing, Contextualized PD</td>
</tr>
<tr>
<td>Theme 4</td>
<td>Learning from Each Other</td>
</tr>
<tr>
<td>Theme 5</td>
<td>Extending across the curriculum</td>
</tr>
</tbody>
</table>

**Theme one: Discourse Makes a Difference**

Making meaning through discourse is essential for students' mathematical understanding (Griffin et al., 2013; Hufferd-Ackles et al., 2004; Martin et al., 2015; Munson, 2019; Smith & Stein, 2018). A discourse-rich environment enhances student learning (Walter, 2018) and allows for higher-level problem-solving skills (Murata, 2017). Sociocultural theory argues that acquiring new knowledge through discourse can transform students' thinking (Vygotsky, 1978). Developing a discourse community, however, is essential but challenging for teachers (Firmender et al., 2014; Griffin et al., 2013; Munson, 2019; Webb et al., 2019). Creating a successful discourse community requires teachers to change their practices (National Council of Teachers of Mathematics [NCTM], 2000;). This case study adds to the research on effectively supporting teachers as they change their practices to include discourse-based teaching. Participants in this
study desired to change their teaching, but it took extended time for them to change their teaching practices (Shabani, 2016). Teachers need to change their beliefs about mathematics education and see the positive impact of discourse before adopting new practices (Jansen et al., 2017; Murphy, 2015; Perry et al., 2015). Chloe and Donna needed to see the impact of discourse on their students’ mathematical understanding before they were prepared to change their practices (Guskey, 2003).

At the beginning of this research study, Donna embraced the idea of discourse in the classroom to engage all students in learning. Donna saw discourse as a way for students to "help each other get the right answer." She still believed her primary role was to ensure her students understood procedures. "They need to know what to do to solve it." Donna comes from a traditional mathematics teaching background where the teacher teaches, and the students do what the teacher directs (Brandefur et al., 2021). Donna’s resistance to change follows research which shows that teachers often teach the way they were taught (Lortie, 1975), and the choices they make in their teaching practices are related to their identity as a teacher (Lerman, 2009). Donna saw mathematics as the procedural memorization of facts and procedures, so she taught that way.

At the end of Phase One interview, Donna agreed there were multiple ways to solve a problem but insisted students need to learn the "right way" in the end. What she did change in her practices was the use of multiple tools. She stated, "I see how the different math tools can help different students."
shows that changing teaching practices takes time (Anderson et al., 2018). Adding various tools was a step in the right direction for Donna.

Phase Two of the PD was formatted as a Community of Practice (CoP). Within this structure, Donna could collaborate and reflect with her peers. During this round of PD, she found "a chance to talk about teaching and support to try new things." After developing discourse routines, Donna felt comfortable "allowing students to help each other explain." She and her students needed the routine to support their growing discourse practices (Sfard, 2008).

In an informal conversation before her final observation and interview, Donna shared a pivotal experience in changing her practices. She was sick and did not have the energy to stand up and go through the mathematics problems, so she let the kids do it. "I was amazed at how well they could do the explaining. They didn't need me to do it for them." Donna shared, "I learned how important explaining is. When they can explain it, they know how to get the right answer." She saw that when her students put their ideas into words, they could clarify their thinking and develop a deeper understanding supported by prior research (Munson, 2019). From that day on, she added as much partner practice time as possible.

In her final interview, Donna changed her views of mathematics and teaching. Never once in the interview did she mention the "right answer." It was about explaining and understanding mathematics and "finding their way." She encouraged students to "do what you need to do to solve the problem and then explain it." Similar to Webb, Franke, Ing, Turrou, Johnson, and Zimmerman's
research, as Donna probed students to share their thinking, she found them sharing more with peers independently. Donna shared that this was something "she always did," but follow-up questions helped her realize that she did not always do that, but now it is her "new normal." This idea follows Guskey’s (2003) research, as Donna’s teaching practices changed when her beliefs about her students’ mathematical abilities changed.

Through Phase One of the PD, Chloe embraced the idea that multiple ways exist to solve and explain a mathematics problem, a vital component of the 5 Practices for Orchestrating Productive Mathematics Discussions (Smith & Stein, 2018) and a component of the Ready Mathematics curriculum (Curriculum Associates, 2020). Throughout her lessons, she encouraged her students to try different ways and practice sharing their thinking. Chloe had students present their ideas to the class but chose those who had the correct answer and solved it the way the curriculum intended. Like many teachers, Chloe could not move beyond her personal and traditional mathematics learning experiences, where the correct answer is the lesson's focus (Boaler, 2018).

The 5 Practices (Smith & Stein, 2018) PD impacted Chloe’s teaching practices. She found the "steps easy to follow," giving her "ways to plan." Her biggest challenge was "anticipating." She was not sure what students would need help with or the mistakes they might make. "It's not in the [teacher's] book." She felt she needed more time to practice the steps and learn the curriculum, and she might be able to know more. This belief follows research that states that
for teachers to support student thinking, they need to understand what students are thinking (Munson, 2019).

Adding peer-to-peer discourse was more of a challenge for Chloe. She worried, "You know my students, they struggle." A very active group of first graders kept her needing to control the mathematics lesson. She also shared that it is hard for her to make changes in the middle of the year. "If I do not start the year with it, it is hard to incorporate m d-year. Next year I will start with more than I did this year." Similar to Baxter's (2002) research results, Chloe needed more time to build discourse routines in her classroom environment. When routines were established, Chloe said she felt more comfortable “letting the students do the talking.” Her students could use discourse to support their learning (Sfard, 2008).

At the end of Phase Two, Chloe had an entirely different view of discourse. She had weekly partners with peer-to-peer discourse as a part of her regular routine. She shared that she has grown in "asking students better questions and asking a student who gets it to explain one who struggles." This concept follows Martin, Polly, McGee, Chuang, Lambert, & Pugalee's (2015) research that teachers' use of questions impacts student learning. Her students developed the skills to question and support each other through Chloe's support, thereby advancing their mathematical understanding (Munson, 2019; Murphy, 2015). Chloe continued, "I am not the keeper of all information, and these students have the knowledge." Similar to Steele, Mercer, and Howe (2012),
Chloe learned that sometimes they can "explain it better using kid-friendly language instead of my formal math terminology."

Participants in this study started with no experience with discourse and only traditional teaching experiences. As prior research has shown, contextualized PD with opportunities for implementation, feedback, and reflection supported Chloe and Donna until they were prepared to use discourse to develop a mathematical understanding (Baxter et al., 2002; Michaels & O'Connor, 2015; Munson, 2019). Through the PD, data shows that both teachers found the value of student ideas and explanations and learned how to support and respond to their students (Murata et al., 2017). They both created mathematical routines that encouraged student discourse. From a commognitive perspective, Donna and Chloe now support their students in developing their mathematical discourse and support them with opportunities to develop, change and extend that conversation (Sfard, 2008).

**Theme two: Going Beyond the Book**

Before PD, both participants were prepared to teach mathematics from the teacher’s guide, doing "what the book says." Chloe and Donna believed their job was to "get through the curriculum." They were nervous as it was new and "different from how I have taught before." In the first PD session, each had a goal revolving around the curriculum. Chloe’s goal was to "learn how to use the new program," while Donna's was to "learn how to make Ready Mathematics (Curriculum Associates, 2020) work." Their focus was on the curriculum rather than their students. After the first phase of PD, Donna and Chloe still used the
teachers' guide to focus their planning and instruction. Teachers focus their learning on the parts of their practice they want to improve (Kennedy, 2016). Donna and Chloe’s goals were to use the new curriculum, and that was the focus of their learning. It is important to remember that PD requires not only adopting new practices but also abandoning old ones (Kennedy, 2016).

Chloe and Donna had different needs and goals in Phase Two of the PD. Chloe wanted to improve her teaching with *Ready Mathematics* (Curriculum Associates, 2020). She needed opportunities to observe best practices in using discourse so she could "see what I am supposed to do." On the other hand, Donna wanted to focus on guiding students to know what to do. She indicated that she needed more "time to practice and learn." These goals shifted the PD to include more concrete classroom discourse examples. Both teachers needed additional knowledge and experiences with discourse to support their use of discourse-based teaching strategies (Darling-Hammond et al., 2017). Many examples did not involve *Ready Mathematics* (Curriculum Associates, 2020) which shifted the focus from the curriculum to discourse. By shifting the PD plan away from the curriculum, participants learned about discourse in general and observed its impact, supported by prior findings (Linder, 2011). Effective PD plans can lead teachers down different paths to present different aspects of teaching (Murata et al., 2012). At the beginning of this study, Chloe and Donna focused on teaching the curriculum. After Phase One, they focused on teaching practices that supported student conceptual understanding.
During Phase Two, participants grappled with the use and challenges of discourse with their students and then discussed and reflected during the CoP (Gomez Zwiep & Benken, 2013). After PD, Chloe and Donna changed their teaching practices to go beyond the book. They did not just “do what the curriculum says” but used practices to support discourse and mathematical understanding. They had observed the impact of discourse on their students and teaching practices. Donna often changes the lesson structure to include peer collaboration. She finds it is "better for the kids to practice and explain things together." It also gives her time to check in with her students to "make sure they understand." Chloe has added daily data, a short mathematical review time where students led the discussion and explain their thinking, into her morning routine for review and supports students to "use the strategy that works for them and not just the one in the book."

**Theme three: Learning from Each Other**

Collaborative approaches have effectively changed teaching practices beyond the individual classroom (Darling-Hammond et al., 2017; Olanoff et al., 2021). Collaboration means that participants work together to construct common knowledge (Mercer & Howe, 2012). Sociocultural theory states that learning is a social endeavor (Driscoll, 2005) and was used as background knowledge when creating the Community of Practice (CoP). Informed by this sociocultural theory understanding, these research findings show that the CoP can positively change teachers’ practices to include discourse-based strategies.
In the first phase of PD, teachers collaborated during PD sessions to plan lessons and anticipate student responses, misconceptions, and needs. However, this collaboration was not routinely extended beyond the PD session. Participants tended to focus on their own teaching practices and needs. In their research with the National Health Service, Pykro, Dörfler, and Eden (2017) noted that PD is more effective when participants collaborate throughout the PD instead of just a focus on the sharing of information. At the end of the PD, Chloe shared that she gained the most from "time talking with others." Donna enjoyed the time to "think and plan together."

In the second phase of the PD, participants asked for a CoP to be developed. One participant shared in the focus group interview, "I learn better when we can talk about it and help each other." Donna stated, "I like to talk things through." Using the CoP professional development plan created a different balance among the participants. Everyone was an "expert" and shared their knowledge; everyone needed more knowledge to succeed. While the researcher led the PD sessions, all participants shared their ideas and experience for the group's betterment. This sharing is typical of CoPs as they often create a sense of togetherness and mutual engagement (Pykro et al., 2017). Outside the PD sessions, participants shared videos, talked about mathematics lessons, shared resources, and gave suggestions when a peer struggled. All teachers' perspectives and knowledge helped create more success for all (Buysse et al., 2003).
Phase Two ended as teachers' priorities changed, and they felt ready to "try it on their own." While participants "enjoyed spending time learning from each other" and "liked being able to share ideas and get new ones." Participants indicated this could be done more informally with grade-level peers. Chloe shared, "I want to team up with H [a teacher not in the CoP] as I feel like she missed out on many of our conversations." She felt that "I could help her now." Donna felt confident in how her mathematics teaching had changed and needed time to focus on her family. She was moving schools at the end of the year and hoped, "I can find a group like this at my new school."

**Theme four: Defining Ongoing, Contextualized PD**

The original PD plan was for a semester of ongoing and contextualized PD to support teachers as they implemented the new Ready Mathematics Curriculum (Curriculum Associates LLC, 2020). The planned PD was significantly more than the one-day training provided to teachers by the district before the school year started. Teachers received 36 hours of direct, specific PD and approximately 20 hours of indirect, individual support and feedback throughout the two-phased PD plan. The PD plan centered around the new curriculum using the 5 Practices for Orchestrating Productive Mathematics Discussions (Smith & Stein, 2018) as a resource and guide to support teachers’ use of discourse in the classroom. PD sessions were organized to support teachers in implementing the practices with the Ready Mathematics (Curriculum Associates LLC, 2020) lessons. Both teachers involved in the PD shared changes in their teaching and
students' mathematical understanding. Data analysis of observations and interviews shared a different story.

While this study included many aspects of effective PD, (a) it was content focused, (b) included active learning, (c) supported collaboration, (d) it used modeling, (e) it offered time for reflection, and (f) was of sustained duration (Darling-Hammond et al., 2017; Desimone, 2009; Kennedy, 2016), it was not effective in a complete change towards conceptual teaching practices in Phase One. While Donna had added student-student discourse, the interactions were focused on the right answer. Chloe had increased her discourse to be more transitional and focused on explanations, but she needed to include student-student discourse in her mathematical routine. Teachers need multiple learning opportunities before influencing their practices and beliefs (Darling-Hammond et al., 2009; Kennedy, 2016). Findings showed that both participants needed more time and opportunities to continue their development. A second phase of PD was implemented in the Fall of 2022.

In Phase Two, a community of practice (CoP) was developed. Based on focus group responses, participants felt they needed (1) time to talk about what they are teaching, (2) opportunities to observe discourse in a classroom, (3) feedback about their implementation, (4) time to work together to plan and get an idea of what actually to do in their classroom. A CoP was created for participants to collaborate and improve their teaching practices (Gee & Whaley, 2016; Olanoff et al., 2021; Wenger-Trayner & Wenger-Trayner, 2015).
Using a CoP for this phase of PD allowed participants to have a say in how the PD was conducted. Situating PD around participants' classrooms and teaching allows teachers to connect the learning to their classroom (Darling-Hammond, 2017; Lave & Wegner, 1991). Each session started with sharing their discourse implementation, reflection, and feedback on their practices and ended with an idea of what they needed next, which are essential factors in changing teaching practices (Gee & Whaley, 2016; Olanoff et al., 2021; Singer et al., 2011). The PD aligned with research showing that PD should be connected to curriculum and classroom materials (Darling-Hammond, 2017). Post-PD interviews showed that the participants felt the same way. Donna said, "It helped me to see and hear what others were doing." Chloe benefited from "taking the time to talk about the lessons and plan what to teach." When better asked about the difference in PD Phases, both teachers shared that they enjoyed the second phase because we were all learning and supporting each other.

There is not a single definition of what sustained PD means (Darling-Hammond et al., 2107). This study adds to the research that contextualized and ongoing PD is necessary to make noteworthy changes in conceptual teaching practices.

**Theme five: Extending across the curriculum**

This research study focused on the impacts of PD on the implementation of mathematical discourse, but unexpected results showed an impact across the curriculum. Both teachers shared that they now use discourse throughout their day in all subjects. Chloe uses "weekly partners, so they know whom they will
talk to at any time." Donna told her students to "use discourse to talk about stories we read and explain their thinking." Both have students use "disagree and agree hand signals" throughout the day. As Darling-Hammond's (2017) research shows, teachers choose PD opportunities to expand their skills and increase their effectiveness. Chloe and Donna wanted to improve their mathematics teaching but found good teaching practices that supported student learning and found success using them in multiple content areas (Guskey, 2003). The goal of PD is to give teachers time and space to grow as educators (Anderson et al., 2018). Both participants grew beyond just their mathematical teaching practices.

A discourse-filled environment allows students multiple opportunities to enhance their learning (Walter, 2018). Discourse is a skill that can extend and support the understanding in all STEM subjects (Larson, 2017). When students can explain their thinking and discuss others’ ideas, their understanding increases (Webb et al., 2019). Donna and Chloe embraced this idea by adding discourse throughout the school day. They created discourse expectations and allowed students to think and engage with peers. A majority of their discursive practices changed from monological to dialogic, focusing on explanation-building and developing understanding.

**Theoretical Connections**

Commognition and Sociocultural theories were used as the theoretical frameworks for this research study. Commognition theory was the basis of the student discourse portion of this research study. The commognitive perspective states that mathematical learning is a conversation with oneself (Sfard, 2008).
Using classroom discourse assists students in developing their individual discourse (Nachlieli & Heyd-Metzuyanim, 2022). Through the study, Donna and Chloe witnessed the impact of those classroom discourses in developing mathematical understanding. Donna found that "they understand more when they can explain it." She continued, "If they can't explain it, they probably don't really understand." From the commognitive perspective, the restating of a mathematical narrative supports the solidification of knowledge (Sfard, 2008).

Chloe found that her students often addressed misconceptions more effectively than she could. They can "explain it better using kid-friendly language instead of my formal math terminology." Using the commognitive lens, her students use object-level discourse to extend a peer's understanding of a concept when her meta-level discourse is too challenging for them (Sfard, 2008).

Developing mathematical routines is also a key component of commognition (Nachlieli & Heyd-Metzuyanim, 2022; Sfard, 2008; Voskoglou, 2019). Chloe and Donna successfully used discourse practices once they secured mathematical routines. These routines assisted their students in several ways. Classroom routines assisted students in focusing on their mathematical discourses. Mathematical routines, or strategies, allow students to solve and prove their mathematical thinking (Shinno & Fujita, 2021). Routines assist students in actively participating in mathematical discourse and developing their mathematical understanding (Sfard, 2008).

Sociocultural theory was used as a foundation for the PD portion of the research. Sociocultural theory states that the construction of knowledge comes
from social interaction (Mercer & Howe, 2012; Shabini, 2016; Vygotsky, 1978). It further states that PD should focus on the needs and goals of the participants (Shabini, 2016). In both phases of PD, pre-assessments were used to determine the focus of teaching content. Collaboration and discussion with peers were critical components of each PD session. From a sociocultural perspective, the participants provided a collective scaffold for each other to develop new teaching practices (Shabini, 2016). They supported each other in the learning process.

Sociocultural perspective also states that developing shared understanding and behavior norms takes time (Mercer & Howe, 2012; Shabini, 2016). In Phase One, there needed to be more time for collaboration. While teachers had time during the PD sessions, it was not encouraged outside the PD sessions. This caused collaboration to be disjointed. Effective collaboration needs to be ongoing to allow the development of knowledge (Voskoglou, 2019)

Goals of Action Research

Herr & Andersons' (2015) five goals of action research were used to determine the quality and success of this research study. The goals of action research focused on research development and were used to determine the success and validity of the study.

Goal 1: The generation of new knowledge

Conceptual mathematics and discourse were the key focuses of knowledge generation throughout this research study. The PD plans specifically focused on developing a new mathematical understanding for participants. Data shows that participants changed their teaching to use discourse-based teaching
practices. Both participants raised their SBTP scores, Donna from 3.25 to 3.95 and Chloe from 3.55 to 4.7. Their overall DIT indicators went from mostly monologic to transitional and dialogic. Moreover, their use of conceptual practices increased from 0.7 to 2.7 (Donna) and 0.8 to 2.9 (Chloe) on the MCOP². The contextualized CoP supported participants in changing their practices and understanding of conceptual mathematics instruction.

**Goal 2: The achievement of action-oriented outcomes**

This research study aimed to increase discourse and conceptual mathematics teaching use in participants' classrooms. This was accomplished for both participants. Donna completely changed her teaching to include discourse for most of her lessons. After the PD, she stopped using the teachers' guide to make decisions and listened to her students. Donna shared the importance of “students helping each other understand.” Chloe made student-student discourse a part of her mathematics routine. Her students could explain their thinking and support peers who needed help. Chloe learned she is not the only "keeper of knowledge" in the classroom. Both teachers changed their practices for improved student learning.

**Goal 3: The education of the researcher and participants**

Educational action research is used to improve teachers' pedagogy and practice (Clark et al., 2020). In this research study, the MCOP² data (Donna- 0.7, Chloe- 0.8) and SBTP data (Donna- 3.25, Chloe- 3.55) showed that both participants used traditional teaching practices at the beginning of the study. They followed the curriculum and tried to do what it said. Through the
implemented PD plan, both teachers could see the impact of discourse and change their practices. Data from the MCOP² data (Donna- 2.8, Chloe- 2.9) and SBTP data (Donna- 3.95, Chloe- 3.4.7) show these changes. Interview data showed that these changes extended beyond mathematics to other content areas. Donna supported students in using discourse across the classroom, and Chloe had “weekly partners,” allowing students to use discourse throughout the day.

**Goal 4: Results are relevant to the local setting**

While the small sample is not statistically significant, the results are relevant in the local setting. When *Ready Mathematics* (Curriculum Associate LLC, 2020) was adopted in the district, one day of PD was prepared for teachers. This research study shows that this was not enough for teachers in my district. This researcher hoped a semester-long PD session would be enough, but another semester was needed before teachers felt confident to tackle the new teaching practices independently. Next year, the school is getting a new reading curriculum, and this study can support the administration in PD decisions related to sustained, contextualized PD.

**Goal 5: A sound and appropriate research methodology**

Case study research is a sound methodology as it allows for the intense analysis of learning situations (Schoch, 2020: Yin, 2018). This case study gathered data on two teachers as they participated in two phases of PD. While the PD plans for each phase differed, the researcher was consistent with data collection and analysis (process validity). Member checking (Brit, 2016) and a
critical friend (Feldman et al., 2018) helped ensure the authenticity of the research plan and analysis.

**Professional Development Evaluation**

This research sought to determine the impact of a PD program on teachers' use of discourse and conceptual mathematical strategies. Guskey’s (2002) 5 levels for evaluation of the impact of PD were used for analysis.

1. Participants' perceptions
   
   Were they satisfied with the PD experience?
   
   What were the positives and negatives of the PD plan?

2. Participants' learning
   
   Did the participants acquire new knowledge or skills?

3. Organization Support and Change (participating school)
   
   What was the impact on the school?
   
   Did it affect the school climate or procedures?

4. Participants’ use of new knowledge and skills
   
   Did the participants use the new knowledge and skills?

5. Student learning outcomes
   
   What was the impact of the PD on students?
   
   Did it affect student performance?

This research focused on four of them: participants' perceptions, participants' learning, the use of new knowledge and skills, and student learning outcomes. An impact on the school organization was an unintended but notable impact.
Participants’ perceptions of mathematics teaching and individual needs were vital data collection components. Their perception of the PD and how it relates to their practice impacts its success (McGee et al., 2013). Individual interviews allowed participants to share their views of their teaching practices and shed light on how the PD plan supported participants throughout the study. Both participants shared that participating in the PD helped make notable changes in their beliefs and teaching practices. Teachers need PD grounded in their classroom practices (Kennedy, 2016; Kutaka et al., 2016; Svendsen, 2020). This PD plan focused on their individual journeys toward discourse-based teaching. Before PD, Donna perceived mathematics as "knowing how to get the right answer." She felt the most crucial thing she should do was teach her students the procedures they needed to get the right answer. She spent most of her mathematics lessons in the front of the classroom, showing students what to do while students copied her work in their workbooks. After the two phases of PD, Donna had a new view of mathematics. Donna believed the PD helped her to see the benefits of "talking and explaining" and supported her as she shifted her practice to facilitating and extending student discourse.

Before PD, Chloe perceived her mathematics instruction as "do what the [teacher's] guide tells me." She opened the book each day and taught the next lesson. After phase 1 PD, Chloe found Smith & Stein's (2018) 5 Practices for Orchestrating Productive Mathematics Discussions another guide to follow. This first phase of PD gave her the structure she needed to try something new. The
CoP in Phase Two gave her the confidence to step out of her comfort zone. She saw how students benefited from the "discourse and explaining their ideas." She was ready to "move past the book" and "do what her students needed."

Participating in the CoP allowed her to share ideas and collaborate on new teaching practices (Voskoglou, 2019). Based on changes in participants’ perceptions, the implemented PD plan effectively supported teachers’ needs.

**Participant Learning**

The acquisition of knowledge about conceptual mathematics and discourse was the basis of the PD phases. When this research began, the discourse survey showed that neither teacher knew about discourse and had not used it in their mathematics instruction previously. Teachers’ practices are influenced by their beliefs (Mapolelo & Akinsola, 2015). In this study, both teachers learned mathematics using traditional methods and taught using those same methods. They needed PD to support their learning of discourse and the teaching practices that support students using discourse to develop their mathematical understanding (Munson, 2019).

The PD plan was designed around Chloe and Donna’s prior knowledge. Effective PD must assist teachers in connecting their current knowledge with new practices (Murata et al., 2012). The first phase of PD began with an introduction to conceptual mathematics and the importance of discourse in instruction using the book *5 Practices for Orchestrating Productive Mathematics Discussions* (Smith & Stein, 2018). Phase One explained the need for discourse and presented a structure for implementing it in the classroom. This structure
scaffolded participants as they implemented new teaching practices in their classrooms. At the end of Phase One, both teachers ranked their discourse knowledge higher in their final discourse survey. Chloe changed her ranking from a one to a four on a five-point scale. Donna, from one to two. Interview answers shared further understanding of discourse. Chloe stated that discourse is “when kids are talking and explaining about math.” Donna shared that when students use discourse, “they are talking about what they are learning.” Both understood that discourse is not just talking but also looking for mathematical explanations (Jansen et al., 2017). Regarding participant learning, the PD was successful at the end of Phase One. The second phase of PD was needed to reach Guskey’s (2002) next level of PD impact, participant use of new knowledge and skills. Effective teaching depends on more than teacher knowledge; it depends on how that knowledge is used in the classroom (Mapolelo & Akinsola, 2015).

**Participants use of new knowledge and skills**

Taking the knowledge of discourse and using it in the classroom was the ultimate goal of this research study, as it is not the knowledge but the change in teaching practices that will impact student learning (Firmender et al., 2014). Observations during the research focused on using the knowledge gained in PD sessions to implement teaching practices in the classroom. While the need to follow the curriculum and keep control of the classroom were hurdles to overcome for participants, in the end, both teachers could see the positive impact of discourse in their classrooms and make changes to their teaching practices.
When teachers see the impact of new teaching practices on student learning, they are more likely to continue the practices (Guskey, 2003).

Donna completely changed her teaching practices to include peer discourse. She did not stand in front of the room and model but walked around and supported students as they discussed the mathematics concepts. When discussing discourse, Donna stated it was “something she always did.” Discourse was now a natural part of her teaching practices.

Chloe changed her mathematical routines to allow students to explain mathematics and support other students with their misconceptions. She was no longer the “keeper of knowledge.” She understood that students had the knowledge to support each other. She sometimes felt her students could explain it better than she could.

Teachers need PD to balance new learning about and the implementation of discourse before they feel successful with new practices (Baxter et al., 2002). This PD plan was successful in terms of participant use of their new discourse knowledge and skills. Both have discourse as a regular part of their mathematical routine.

**Organization Support and Change**

The scope of this action research study prevented the researcher from focusing on the impact of PD on the participating school as a whole. As with most action research, this study focused on improving the practices of participating teachers (Clark et al., 2020; Koshy, 2010). It did not extend to the school as a whole. However, data analysis showed a change in the school environment.
Creating a CoP was something new for the participating school and had a positive impact. The CoP allowed for the exchange of information and gave teachers support in changing practices (Olanoff et al., 2021). A CoP builds relationships between participants and creates built-in resources (Pykro et al., 2017). Teachers now have support from each other instead of just working independently. In the final interview, both participants shared the positive results of CoP on their practices and expressed the desire to create new ones. Chloe wanted to work with her grade-level partners: "I think we need more time to collaborate and work together." Donna was sad to leave the school and hoped to find "something like this at my new school." Both participants are motivated to participate in more CoPs to improve the school as a whole, showing an ongoing impact of PD.

**Student Learning Outcomes**

When determining the effectiveness of teacher PD, it is vital to consider the impact on students (Desimone, 2009; Guskey, 2002). While the focus of this research study was on the impact of PD on teaching practices, the impact on student discourse was evident in the data.

Research question two focused data collection on students' opportunities for discourse. Prior to PD, Chloe and Donna were the teachers, presenting information to students and helping them learn procedures to, as Donna said, “get the right answer.” Teachers could observe, implement, and reflect on new teaching practices throughout the two-phased PD. Teachers need time to observe and practice instructional strategies while developing their content
knowledge in PD (Jansen et al., 2017). This observation and reflection allowed Chloe and Donna to experience and see how discourse can impact student mathematical understanding.

At the end of PD, students in both classrooms were engaged in transitional and dialogic discourse (Reznitskaya et al., 2012). Most of their mathematical learning time, 64% for Chloe’s class, and 90% for Donna’s, involved discourse. Students were allowed to explain their thinking, recognize misconceptions, and problem solve. All three are vital for developing mathematical understanding (Gellert, 2012; Mercer & Sams, 2008; Muson, 2019). Mathematics was no longer the memorization of procedures, but the development of understanding, a positive outcome on student learning.

Limitations

This study aimed to determine the impact of professional development on the teaching practices of elementary classroom teachers. The sampling procedures used to determine case study participants limited the study. A convenience sample was selected as observations, professional development sessions, and interviews needed to be accessible to participants and the researcher. A convenience sample narrows generalizations to other populations (Jager et al., 2017). Future studies should focus on participants from various schools across the district.

A second limitation of the study was the time break between Phase One and Phase Two. The researcher’s original plan was only to have one phase of PD. Data analysis and informal conversations with participants in the spring of
2022 showed the need for additional PD. Educational action research encourages better teaching practices (Sáez & Gracia, 2022). These participants needed more time and support, leading the researcher to conduct the second phase of PD. Keeping with the cyclical and iterative nature of action research (Clark et al., 2020; Elliott, 1991; Efron & Ravid, 2019), the PD plan changed to meet the needs of the participants. Future studies should follow a continuous PD plan where teachers receive all PD in one phase.

The third limitation was the need for more data collected on the impact on student learning. An important factor when examining effective PD is how it affects students' learning (Desimone, 2009; Guskey, 2002). As this action research used a case study design, the focus was on explaining the circumstances around the PD (Yin, 2018). Examining the impact on student mathematical understanding was beyond the scope of this study. Future studies could move beyond a two-person case study to focus on changes in teaching practices and how they impact student mathematical understanding.

**Implications for Practice**

With these limitations in mind, findings from this study can be used when constructing PD plans for teachers. Professional development is the key to supporting change in teacher practices (Desimone, 2009; Guskey, 2003; Kennedy, 2016). This action research study showed that one time, snapshot PD is not effective in changing teacher practice (Desimone, 2009; Murata et al., 2012; Sztajn et al., 2020). Teachers need ongoing, contextualized PD, which allows them to connect learning to their students and their classroom.
Professional development needs to move beyond the traditional segmented, outside of the classroom sessions (Desimone, 2009; Kutaka et al., 2016), to building communities of practice where teachers have the opportunity to work together to learn, support, reflect, and shift practices to meet the changing expectations and needs of students. Many teachers need to gain experience with discourse and conceptual mathematics practices. They need the opportunity to observe and practice new teaching strategies to see how they can positively impact student mathematical understanding. This study shows that a PD path of an ongoing, sustained Community of Practices can support teachers in changing their practices and supporting students in this new learning.

Summary

This holistic, mixed-methods case study investigated the impact of contextualized professional development on the use of discourse-based mathematical practices in elementary classrooms. Using a two-phased PD plan, data were collected to identify and explain participants’ changes in the use of discourse in the classroom. Phase One of PD showed shifts in participants’ knowledge and teaching practices towards conceptual and discourse-based practices. However, it was not enough for the participants to feel comfortable with the new practices for students to have the opportunity for productive discourse. The Phase Two CoP allowed participants time and support to continue their personal growth and change in the classroom. Participants had the time to set up discourse-based routines, reflect on their role as teachers, and learn to support students in explaining their mathematical understandings. Findings show that
contextualized, learner-centered PD focusing on the implementation of new teaching strategies, connected with reflection and feedback, can positively support teachers in changing their practices.
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Appendix A – Standards of Mathematical Practices

SMP1. Make sense of problems and persevere in solving them.

SMP2. Reason abstractly and quantitatively.

SMP 3. Construct viable arguments and critique the reasoning of others.

SMP 4. Model with mathematics.

SMP 5. Use appropriate tools strategically.

SMP 6. Attend to precision.

SMP 7. Look for and make use of structure.

SMP 8. Look for and express regularity in repeated reasoning.
## Appendix B – Professional Development Plan

### Table B.1 – Organization of Professional Development Plan

<table>
<thead>
<tr>
<th>PROFESSIONAL DEVELOPMENT SESSIONS</th>
<th>PHASE 1</th>
<th>PHASE 2</th>
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<tbody>
<tr>
<td>Introductory Task</td>
<td>Teachers have the opportunity to practice discourse skills</td>
<td>Introductory Task</td>
</tr>
<tr>
<td>Individual Sharing time</td>
<td></td>
<td>Varied based on participant wants</td>
</tr>
<tr>
<td>Content Focus</td>
<td>Productive Discourse (Smith &amp; Stein, 2018)</td>
<td>Content Focus</td>
</tr>
<tr>
<td>Planning Time</td>
<td>Integrating Productive Discourse skills into the curriculum</td>
<td>Goal setting</td>
</tr>
<tr>
<td>Review/Questions</td>
<td>Summation of discourse skills and answering individual questions</td>
<td></td>
</tr>
<tr>
<td>MID PD DATA COLLECTION</td>
<td>Observation (MCOP² &amp; DIT)</td>
<td>Observation (MCOP² &amp; DIT)</td>
</tr>
<tr>
<td>Individual Interviews</td>
<td></td>
<td>Individual Interviews</td>
</tr>
<tr>
<td>POST-PD DATA COLLECTION</td>
<td>Observation (MCOP² &amp; DIT)</td>
<td>Observation (MCOP² &amp; DIT)</td>
</tr>
<tr>
<td>Individual Interviews &amp; SBTP</td>
<td></td>
<td>Individual Interviews &amp; SBTP</td>
</tr>
<tr>
<td>INFORMAL SUPPORT</td>
<td>Individual support given as needed. Data from informal conversations collected</td>
<td></td>
</tr>
</tbody>
</table>
Appendix C – Discourse Survey

Name ____________________

Rate your level of discourse knowledge

1  2  3  4  5

What is your personal experience using discourse?

What is your experience using discourse with students?

How do you plan on using discourse in your classroom?

What additional training needs do you have about discourse-based teaching?
Appendix D - Interview Protocols

Introduction:

The focus of this research project is to determine the impact of ongoing, learner-centered PD on the use of discourse. You have agreed to participate in the research study. I want your initial thoughts and ideas about this semester's Ready Mathematics curriculum, discourse use, and goals.

Research Questions:

1. How does teacher participation in discourse-focused professional development influence conceptual teaching practices?
2. How does teacher participation in discourse-focused professional development influence student discourse?
3. How does teacher participation in discourse-focused professional development influence teachers’ beliefs regarding conceptual mathematical instruction?

Before Professional Development

1. How do you feel about the Ready Mathematics curriculum? What are your thoughts?
2. Have you used discourse in your classroom before? If so, what are your thoughts on the use of discourse?
3. What support do you need to implement the *Ready Mathematics* curriculum?

4. What are your goals for the PD and the use of discourse?

**Post Observation**

1. Tell me about your lesson.

2. What were some challenges and successes in the lesson?

3. Did you adapt the lesson from your original plan?

4. What did you think went well, and what do you need to work on?

**Post Professional Development**

1. What are your thoughts on teaching math after the PD?

2. In what ways did the PD change your thinking and beliefs about teaching math?

3. How do you think teaching changed after the PD?

3. What additional support do you need at this point?
Appendix E - Professional Development Plan – Phase 1

General Session Overview

1- Opening Task

Teachers can practice discourse with high-quality tasks and use discourse to share their thinking and ideas.

2- PD content – conceptual math

The content was presented for participants to understand better conceptual math and tools to assist students and support teaching in implementing the new curriculum.

3- Discourse specific content

Smith and Stein (2018) *5 Practices for Orchestrating Productive Discourse* as the guiding focus

4- Teacher sharing how discourse/mathematics implementation is going

What is working, not working, or questions they have

5- Small group Lesson Planning with grade-level peers

Time to look at the curriculum and plan for using discourse in their classroom. Teachers used planning sheets to determine how to use each of the 5 practices, think about student misconceptions and plan for questions

6- Goal setting

Each teacher set a goal for implementation in the next two weeks.
Table E.1 – Phase One PD Session Topics

<table>
<thead>
<tr>
<th>Session</th>
<th>Date</th>
<th>Lesson Theme</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8/30</td>
<td>What is productive discourse and conceptual learning</td>
</tr>
<tr>
<td>2</td>
<td>9/13</td>
<td>5 Practices for Orchestrating Productive Discourse overview (Smith &amp; Stein, 2018)</td>
</tr>
<tr>
<td>3</td>
<td>9/27</td>
<td>Conceptual math</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Anticipating</td>
</tr>
<tr>
<td>4</td>
<td>10/11</td>
<td>High quality tasks</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Monitoring</td>
</tr>
<tr>
<td>5</td>
<td>10/25</td>
<td>Multiple strategies</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Selecting</td>
</tr>
<tr>
<td>6</td>
<td>11/8</td>
<td>Peer-to-peer discourse</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sequencing</td>
</tr>
<tr>
<td>7</td>
<td>11/22</td>
<td>Importance of student explaining</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Connecting</td>
</tr>
<tr>
<td>8</td>
<td>12/6</td>
<td>Putting it together / review</td>
</tr>
</tbody>
</table>

- Content modified based on observations, individual interviews and informal conversations
Appendix F - Professional Development Plan – Phase 2

General Session Overview

1- Participant Open Discussion

Participants share how the mathematics teaching is going in their classrooms. The open discussion included ideas and suggestions from all members of the group. There was a time for reflection of what worked well, impact on students and challenges participants were facing.

2- PD content – conceptual math

Conceptual mathematical content and teaching practices were presented for participants to understand conceptual mathematics and the use of discourse in the classroom. Content varied based on the needs, goals and struggles of participants.

4- Discourse examples

Videos and audio sharing of discourse used with students. Focus group interviews results showed participants needed to see and hear what discourse would look like in their classroom. After the videos, there was time for questions, discussion and reflections.

6- Planning and goal setting

Participants looked through lessons for the next couple of weeks to reflect and plan for instruction. Each teacher set a goal for implementation before the next session.
Table F.1 – Phase Two PD Session Topics

<table>
<thead>
<tr>
<th>Session</th>
<th>Date</th>
<th>Lesson Theme</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8/24</td>
<td>Focus Group interview/ Introduction to Conceptual mathematics and Discourse</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Goal Setting</td>
</tr>
<tr>
<td>2</td>
<td>9/13</td>
<td>Discourse in a primary classroom- setting up routines</td>
</tr>
<tr>
<td>3</td>
<td>9/27</td>
<td>Reviewing examples of discourse- what do we want it to look like? What are</td>
</tr>
<tr>
<td></td>
<td></td>
<td>students doing? What is the teacher doing?</td>
</tr>
<tr>
<td>4</td>
<td>10/11</td>
<td>Supporting student explanations</td>
</tr>
<tr>
<td>5</td>
<td>10/25</td>
<td>Loosening the strings- letting students take some control of the lesson</td>
</tr>
<tr>
<td>6</td>
<td>11/8</td>
<td>High Cognitive Tasks to support discussion</td>
</tr>
<tr>
<td>7</td>
<td>1/23 (Original date 12/5- postponed due to snow days.)</td>
<td>Moving your discourse to the next level, from transitional to dialogic</td>
</tr>
<tr>
<td></td>
<td>2/7 (Original date 12/14 – postponed due to snow days)</td>
<td>Where are we going? Sharing discourse examples from upper grades and where our discourse is leading students towards.</td>
</tr>
</tbody>
</table>
### Appendix G – Research Timeline

**Table G.1- Research Timeline**

<table>
<thead>
<tr>
<th>Date</th>
<th>Event</th>
<th>Data Tool</th>
<th>Focus</th>
</tr>
</thead>
<tbody>
<tr>
<td>August 2021</td>
<td>Beginning of school year mandated Introductory Training by Curriculum Associates Implementation of <em>Ready Mathematics</em> Curriculum to begin</td>
<td>Discourse questionnaire MTEBI (Enochs et al., 2000)</td>
<td>Baseline data on participants gathered</td>
</tr>
<tr>
<td>September 2021</td>
<td>Participants selected and interviews given Classroom Observation</td>
<td>Individual interviews MCOP² &amp; DIT</td>
<td>Baseline data gathered on the use of discourse Individual goal setting</td>
</tr>
<tr>
<td>September - December 2021</td>
<td>Bi-weekly PD (credit course) Teaching implement discourse in the classroom after PD sessions</td>
<td>Individual teacher journals Class discussion</td>
<td></td>
</tr>
<tr>
<td>October 2021</td>
<td>Classroom Observation Individual interview</td>
<td>MCOP² &amp; DIT Interview protocol</td>
<td>Data gathered on discourse use Individual experiences shared</td>
</tr>
<tr>
<td>Date</td>
<td>Activity</td>
<td>Methodology</td>
<td>Analysis</td>
</tr>
<tr>
<td>---------------------</td>
<td>--------------------------------------------------------------------------</td>
<td>------------------------------------------</td>
<td>---------------------------</td>
</tr>
<tr>
<td>December 2021</td>
<td>End of PD data collection</td>
<td>MTEBI (Enochs et al., 2000)</td>
<td>Impact of PD on discourse implementation</td>
</tr>
<tr>
<td></td>
<td>Individual interview</td>
<td>Discourse questionnaire</td>
<td>Thoughts on PD, use of discourse and impact on students</td>
</tr>
<tr>
<td>January - May 2022</td>
<td>Individual 1:1 support with participants</td>
<td>Informal interviews</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Informal Interviews</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Researcher Data analysis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Summer 2022</td>
<td>Created a new PD plan for year 2</td>
<td></td>
<td>Data analyzed to identify and create new PD plan</td>
</tr>
<tr>
<td>August 2022</td>
<td>Participants selected and interviews given</td>
<td>Individual Interviews</td>
<td>Individual goal setting</td>
</tr>
<tr>
<td></td>
<td>Focus Group interview</td>
<td>Focus group protocol</td>
<td>PD focus</td>
</tr>
<tr>
<td></td>
<td>Classroom Observation</td>
<td>MCOP² &amp; DIT</td>
<td>Baseline data for yr 2 gathered on the use of discourse</td>
</tr>
<tr>
<td>September - December 2022</td>
<td>Bi-weekly PD Teaching implement discourse in the classroom after PD sessions</td>
<td>Individual Teacher journals</td>
<td>PD plan will be flexible to meet learner needs</td>
</tr>
<tr>
<td>October 2022</td>
<td>Classroom Observation</td>
<td>Observation Protocol</td>
<td>Data gathered on discourse used individual experiences shared</td>
</tr>
</tbody>
</table>
| February 2022  (Postponed due to snow days) | End of semester data collection  
Classroom Observation  
Individual Interview | MTEBI (Enochs et al., 2000) | Impact of PD on teaching practices  
Thoughts on PD / discourse and impact on students |
| January - May 2023 | Researcher data analysis  
Data shared with participants for reliability  
Work on dissertation final product | | |
Appendix H – Complete Data

Table H.1- MCOP² Observation Data

<table>
<thead>
<tr>
<th>Practices</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>Avg.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Chloe</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
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<td>Obs 1</td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0.8</td>
</tr>
<tr>
<td>Obs 2</td>
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<td>2</td>
<td>2</td>
<td>2</td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1.3</td>
</tr>
<tr>
<td>Obs 3</td>
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<td>2</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>2.1</td>
</tr>
<tr>
<td>Obs 4</td>
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<td>2</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>2.0</td>
</tr>
<tr>
<td>Obs 5</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>2.5</td>
</tr>
<tr>
<td>Obs 6</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2.9</td>
</tr>
<tr>
<td><strong>Change</strong></td>
<td>+1</td>
<td>+2</td>
<td>+2</td>
<td>+2</td>
<td>+2</td>
<td>+2</td>
<td>+2</td>
<td>+2</td>
<td>+3</td>
<td>+3</td>
<td></td>
</tr>
<tr>
<td><strong>Donna</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Obs 1</td>
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<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0.7</td>
</tr>
<tr>
<td>Obs 2</td>
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<td>2</td>
<td>1</td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1.3</td>
</tr>
<tr>
<td>Obs 3</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>3</td>
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<td>2.0</td>
</tr>
<tr>
<td>Obs 4</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1.9</td>
</tr>
<tr>
<td>Obs 5</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>2.5</td>
</tr>
<tr>
<td>Obs 6</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>2.8</td>
</tr>
<tr>
<td><strong>Change</strong></td>
<td>0</td>
<td>+1</td>
<td>+1</td>
<td>+1</td>
<td>+1</td>
<td>+1</td>
<td>+2</td>
<td>+1</td>
<td>+1</td>
<td>+2</td>
<td></td>
</tr>
</tbody>
</table>

1- Students were engaged in mathematical activities.
2- Students critically assessed mathematical strategies.
3- The lesson involved fundamental concepts of the subject to promote relational/conceptual understanding.
4- The lesson included tasks with multiple paths to a solution or multiple solutions.
5- The teacher’s talk encouraged student thinking.
6- There was a high proportion of students talking related to mathematics.
7- There was a climate of respect for what others had to say.
8- In general, the teacher provided wait time.
9- Students were involved in communicating their ideas to others (peer to peer).
10- The teacher uses student questions/comments to enhance conceptual mathematical understanding.
### H.2 Standards-based Teaching Practices (SBTP) (Ross et al., 2003) Data

<table>
<thead>
<tr>
<th>SBTP</th>
<th>Pre- PD</th>
<th>Mid- PD</th>
<th>Post -PD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>D  C  M</td>
<td>D  C  M</td>
<td>D  C  M</td>
</tr>
<tr>
<td>I like to use math problems that can be solved in many ways.</td>
<td>3 4 3.5</td>
<td>4 5 4.5</td>
<td>5 5 5</td>
</tr>
<tr>
<td>I regularly have students work through real-life math problems that are of interest to them.</td>
<td>3 3 3</td>
<td>3 4 3.5</td>
<td>4 5 4.5</td>
</tr>
<tr>
<td>When two students solve the same math problem correctly using two different strategies, I have them share the steps they went through with each other.</td>
<td>3 3 3</td>
<td>3 5 4</td>
<td>4 5 4.5</td>
</tr>
<tr>
<td>I tend to integrate multiple strands of mathematics within a single unit.</td>
<td>3 3 3</td>
<td>3 3 3</td>
<td>4 5 4.5</td>
</tr>
<tr>
<td>I often learn from my students during math time because my students come up with ingenious ways of solving problems I have never thought of.</td>
<td>3 3 3</td>
<td>3 5 4</td>
<td>4 5 4.5</td>
</tr>
<tr>
<td>It is not very productive for students to work together during math time. (Note negative)</td>
<td>1 1 1</td>
<td>1 1 1</td>
<td>1 1 1</td>
</tr>
<tr>
<td>Every child in my room should feel that mathematics is something he/she can do.</td>
<td>5 5 5</td>
<td>5 5 5</td>
<td>5 5 5</td>
</tr>
<tr>
<td>I integrate math assessment into most math activities.</td>
<td>2 2 2</td>
<td>2 4 3.5</td>
<td>3 5 4</td>
</tr>
<tr>
<td>In my classes, students learn math best when they can work together to discover mathematical ideas.</td>
<td>4 4 4</td>
<td>5 5 5</td>
<td>5 5 5</td>
</tr>
<tr>
<td>I encourage students to use manipulatives to explain their mathematical ideas to other students.</td>
<td>3 5 4</td>
<td>5 5 5</td>
<td>5 4 4.5</td>
</tr>
<tr>
<td>When students are working on math problems, I put more emphasis on getting the correct answer than the process</td>
<td>2 1 1.5</td>
<td>3 1 2</td>
<td>1 1 1</td>
</tr>
</tbody>
</table>
Creating rubrics for math is a worthwhile assessment strategy.  

In my class, it is just important for students to learn data management and probability as it is to learn multiplication facts.  

I don’t necessarily answer students’ math questions but rather let them puzzle things out for themselves.  

A lot of things in math must simply be accepted as true and remembered. (note - not conceptual based)  

I like my students to master basic mathematical operations before they tackle complex problems. (note- not conceptual based)  

I teach students how to explain their mathematical ideas.  

Using computers to solve math problems distracts students from learning basic math skills. (note- not conceptual based)  

If students use calculators, they won’t master the basic math skills they need to know. (note- not conceptual based)  

You have to study math for a long time before you see how useful it is. (note- not conceptual based)

<table>
<thead>
<tr>
<th>Followed. (note - not conceptual based)</th>
<th>D</th>
<th>C</th>
<th>M</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Creating rubrics for math is a worthwhile assessment strategy.</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>In my class, it is just important for students to learn data management and probability as it is to learn multiplication facts.</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>I don’t necessarily answer students’ math questions but rather let them puzzle things out for themselves.</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>A lot of things in math must simply be accepted as true and remembered. (note - not conceptual based)</td>
<td>3</td>
<td>4</td>
<td>3.5</td>
<td>2</td>
</tr>
<tr>
<td>I like my students to master basic mathematical operations before they tackle complex problems. (note- not conceptual based)</td>
<td>4</td>
<td>5</td>
<td>4.5</td>
<td>4</td>
</tr>
<tr>
<td>I teach students how to explain their mathematical ideas.</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Using computers to solve math problems distracts students from learning basic math skills. (note- not conceptual based)</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>If students use calculators, they won’t master the basic math skills they need to know. (note- not conceptual based)</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>You have to study math for a long time before you see how useful it is. (note- not conceptual based)</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>65</td>
<td>71</td>
<td>68</td>
<td>68</td>
</tr>
<tr>
<td>Mean</td>
<td>3.25</td>
<td>3.55</td>
<td>3.4</td>
<td>3.4</td>
</tr>
</tbody>
</table>

D = Donna  C = Chloe  M = Mean
<table>
<thead>
<tr>
<th>Interaction Type</th>
<th>Authority (T-S)</th>
<th>Questioning (T-S)</th>
<th>Feedback (T-S)</th>
<th>Metalevel Reflection/Connecting (T-S)</th>
<th>Explanation (S-S)</th>
<th>Collaboratio (S-S)</th>
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Appendix I – Three-Cycle Coding Process

<table>
<thead>
<tr>
<th>Pre-PD</th>
<th>Mid-PD</th>
<th>Post-PD</th>
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</thead>
<tbody>
<tr>
<td>get through the lesson</td>
<td>Teaching What to do</td>
<td>Supporting Understanding</td>
</tr>
<tr>
<td>Follow teacher's guide</td>
<td>know what to do</td>
<td>Understanding why it is correct</td>
</tr>
<tr>
<td>Go through the pages</td>
<td>Students know the steps to follow</td>
<td>They need to see to understand</td>
</tr>
<tr>
<td>What Ready says</td>
<td>Showing them the right way</td>
<td>Know which strategy</td>
</tr>
<tr>
<td>Follow lesson plans</td>
<td>Explain what to do</td>
<td>They need to know why an inch is more</td>
</tr>
<tr>
<td>Make sure students get it</td>
<td>Help figure out the answer</td>
<td>There are different ways to do it</td>
</tr>
<tr>
<td>Do each step</td>
<td>Do fact families</td>
<td>Make sure they all understand</td>
</tr>
<tr>
<td>Get the right answer</td>
<td>Know the rules</td>
<td>Many ways to solve it</td>
</tr>
<tr>
<td>Show students what to do</td>
<td>procedures</td>
<td>Explain their ideas</td>
</tr>
<tr>
<td>Finish the pages</td>
<td></td>
<td>Understand how to solve to get the right answer</td>
</tr>
<tr>
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<td>Know why it is right</td>
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</table>
### Table I.2- Phase 1, Theme 2: Student Discourse

<table>
<thead>
<tr>
<th>Pre-PD Student Struggles</th>
<th>Mid-PD Increased Participation</th>
<th>Post-PD Guided Math Talk</th>
</tr>
</thead>
<tbody>
<tr>
<td>challenge</td>
<td>changes</td>
<td>Explain what they did</td>
</tr>
<tr>
<td>Pay attention</td>
<td>Own fact family</td>
<td>I do the teaching, they do the explaining</td>
</tr>
<tr>
<td>Not focused</td>
<td>Share switching numbers</td>
<td>Everyone gets to talk</td>
</tr>
<tr>
<td>Don’t listen</td>
<td>Extra talking</td>
<td>Explaining thinking</td>
</tr>
<tr>
<td>Play with blocks</td>
<td>Write on board</td>
<td>Try to do it the same way</td>
</tr>
<tr>
<td>Just finish</td>
<td>Giving them time</td>
<td>Most of the explaining</td>
</tr>
<tr>
<td>Don’t know what to say</td>
<td>Coming up to share</td>
<td>Sharing ideas</td>
</tr>
<tr>
<td>I did it in my head</td>
<td>Hand signals</td>
<td>Letting them do more teaching</td>
</tr>
<tr>
<td>They can’t explain it</td>
<td>Asking S questions</td>
<td>Let everyone share</td>
</tr>
<tr>
<td>Off task</td>
<td>Talk about what they did</td>
<td>Help them explain</td>
</tr>
<tr>
<td>Can’t sit still</td>
<td>Sharing</td>
<td>Model what to do</td>
</tr>
<tr>
<td>Wait for me</td>
<td>Time to grapple</td>
<td>Do it together</td>
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</tbody>
</table>
Table I.3- Phase 1, Theme 3: Changes in Practice

<table>
<thead>
<tr>
<th>Pre-PD</th>
<th>Mid-PD Making Some Changes</th>
<th>Post-PD Sharing and Explaining</th>
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<tbody>
<tr>
<td>Current Practices</td>
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<tr>
<td>Do what is in the teacher's guide</td>
<td>More talking</td>
<td>Better at explaining thinking</td>
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<tr>
<td>I don’t know</td>
<td>S know what to do</td>
<td>Talk in small groups</td>
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<tr>
<td>curriculum</td>
<td>improved</td>
<td>Explain to friends</td>
</tr>
<tr>
<td>Follow the book</td>
<td>give them time to talk</td>
<td>Using math to explain</td>
</tr>
<tr>
<td>Whatever it says</td>
<td>Makes more sense</td>
<td>Share ideas</td>
</tr>
<tr>
<td>Supposed to do</td>
<td>Trying new things</td>
<td>Talk about math</td>
</tr>
<tr>
<td>Get the right answer</td>
<td>S talked as they rolled</td>
<td>Share with each other</td>
</tr>
<tr>
<td>Do what it says</td>
<td>changes</td>
<td>Don’t listen</td>
</tr>
<tr>
<td></td>
<td>More comfortable</td>
<td>Don’t talk about math</td>
</tr>
<tr>
<td></td>
<td>S know what to do</td>
<td>Daily data- Students led discussion</td>
</tr>
<tr>
<td></td>
<td>Learning ways to improve</td>
<td>Explain the math</td>
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<tr>
<td></td>
<td>Multiple strategies</td>
<td>No curriculum to follow – flexible</td>
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<tr>
<td></td>
<td>Need to follow the book</td>
<td>Getting through lesson</td>
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<tr>
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<td>Learned routine</td>
<td>Student share thinking</td>
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<tr>
<td></td>
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<td>Explain how they did it</td>
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<table>
<thead>
<tr>
<th>Pre-PD Setting up Ready Routines</th>
<th>Mid-PD Students Working together</th>
<th>Post-PD Supporting Students</th>
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<tbody>
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<td>Expectations routines</td>
<td>Peer review</td>
<td>Strategy used</td>
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<tr>
<td>Students need to know what to do</td>
<td>Practice explaining</td>
<td>Why do you pick that one?</td>
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<td>Model for students</td>
<td>S can’t always explain</td>
<td>Explain their thinking</td>
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<tr>
<td>Show what to do</td>
<td>They might not understand</td>
<td>What works for them</td>
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<tr>
<td>Building routines</td>
<td>Worked in groups</td>
<td>Try a different strategy</td>
</tr>
<tr>
<td>Set it up from beginning</td>
<td>I tried to help them explain</td>
<td>Help each other first</td>
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<tr>
<td>Develop a routine</td>
<td>Partners helped</td>
<td>I listen and then help</td>
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<tr>
<td>It’s a math tool</td>
<td>who understood and who needed help</td>
<td>misconceptions</td>
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<td>I have to show them</td>
<td>Weekly partner</td>
<td>Supporting</td>
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<tr>
<td>Can you explain?</td>
<td>Discuss work</td>
<td>questioning</td>
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<td>Help them explain</td>
<td>Explain</td>
<td>They explain better</td>
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<tr>
<td>Take time</td>
<td>Share their work</td>
<td>Kid-friendly language</td>
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<td>Take time before they are ready</td>
<td>What do we need to do?</td>
<td>Explain strategy</td>
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<td>Show them first practice</td>
<td>What did you do next</td>
<td>Students understand</td>
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<td>Who can help?</td>
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<td>Pre-PD</td>
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<tr>
<td>What does it look like?</td>
<td>Feedback</td>
<td>On My Own</td>
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<tr>
<td>Not sure what discourse looks like</td>
<td>I can’t wait to hear what you have to say</td>
<td>comfortable</td>
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<td>How to guide</td>
<td>Not sure how to answer</td>
<td>Teaching changed</td>
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<td>We need to use</td>
<td>Help them learn more</td>
<td>Feel good about where I am</td>
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<td>Unsure how to do it</td>
<td>I can do more</td>
<td>Discourse at different times of the day</td>
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<tr>
<td>Know I need, don’t know how</td>
<td>Explain better so they can explain</td>
<td>Really talking about what they know</td>
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<tr>
<td>I need to see so I have a picture in my head</td>
<td>What am I doing wrong?</td>
<td>Explain it – then they know</td>
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<td>See so I can understand</td>
<td>They don’t get the right answer</td>
<td>On my own</td>
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<td>I am not sure</td>
<td>How do I show them?</td>
<td>Listen more to each other</td>
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<td>My job to help them</td>
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<td>Do math together</td>
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