Clarifying Coaching: A Mixed Methods Analysis of a Math Content-Focused Model and Its Impact on Teachers' Practice, Content Knowledge, and Dispositions

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ABSTRACT

Coaching is increasingly becoming required or recommended as a form of teacher professional development, but the education field has only begun to define the practice and understand its features, especially in regard to its potential to improve math teaching in early childhood contexts. Using mixed methods and a Whole Teacher Approach theoretical framework, this study examined a math content-focused coaching model and its impact on teachers’ math content knowledge, teaching practice, and dispositions including attitudes, beliefs, and confidence. Participants included 141 lead and assistant teachers and 5 coaches working in 27 Head Start centers in Chicago. Teachers at centers randomly assigned to the intervention condition participated in workshops and up to five coaching cycles consisting of planning, observation, and reflecting. Quantitative measures included: (a) the Evaluating Quality Interactions in Preschool Math video observation tool; (b) the Pedagogical Content Knowledge in Preschool Mathematics survey; (c) the Attitudes, Beliefs, and Confidence in Preschool Mathematics survey; and (d) coaching fidelity surveys. Qualitative data sources included: (a) open-ended teacher survey responses; (b) open-ended coach survey responses; (c) coaching logs; and (d) project documents. While there was no evidence of change in teaching practices in the time frame of the intervention (8 months), coaching was found to improve teachers’ confidence in math teaching. This is attributed to an emphasis on planning that included role-play and attention to teachers’ pedagogical content knowledge for math teaching. Results also indicate
that the group coaching format with inclusion of assistant teachers increased collaboration among colleagues.
CHAPTER ONE
INTRODUCTION

As of August 1, 2017, the U.S. Department of Health and Human Service’s Head Start Performance Standards section on Training and Professional Development (§1302.92) requires that as part of a systemic approach to staff development, “A program must implement a research-based, coordinated coaching strategy for education staff.” Centers are free to choose their coaching model as long as it is “research-based” (see Appendix A for the full text of this section in the standards). However, much is still unknown about which features make this relatively new approach to teacher professional development most effective because published studies often fail to describe coaching activities, dosage, underlying philosophy, or coach characteristics. Gaps are especially apparent in the area of preschool math, which is nearly absent from the coaching literature despite increasing awareness of its importance for children’s overall academic achievement. Research about coaching that involves assistant teachers is also rare, despite the common reality of two or more adults working closely together in early childhood classrooms. The objective of the proposed study is to improve understanding of the process of early math coaching and its impact on lead and assistant teachers.

Need for Effective Professional Development

Children arrive in preschool with mathematical interests and budding skills, but they require intentional guidance to reach their full potential (Clements et al., 2004). In order to provide this, teachers need strong pedagogical content knowledge and command of effective
strategies for teaching math (Ball et al., 2008; Darling-Hammond & Bransford, 2005; Hill, 2010). Teacher preparation programs do not always adequately prepare early childhood teachers to teach math (Copple, 2004; Fennell, 2011; Ginsburg et al., 2006; Institute of Medicine, 2015; National Research Council, 2009; Parks & Wagner, 2015). Insufficient preparation can lead to reduced effectiveness in early math teaching. This becomes evident in the limited time early childhood teachers devote to math content during the school day. For example, in a representative sample of 95 Chicago classrooms serving 4-year-old children, Meisels and Howard (2008) found that 22% of classrooms engaged children in math learning daily as opposed to 90% of classrooms which engaged children in daily literacy learning. In addition, early childhood teachers commonly expose children to a narrow range of math knowledge by focusing on counting while neglecting operations, shape, space, measurement and pattern (Copley, 2010). At the same time, they underestimate children’s cognitive capabilities and foster a low level of understanding compared to developmental capabilities documented in research (Ginsburg et al., 2008). Furthermore, early childhood teachers frequently report negative experiences in their own schooling (Drake et al., 2001) and high math anxiety (Copley, 2014; Gresham, 2007). Thus, early childhood teachers, like the children in their care, need additional support to develop their potential.

In a review of 35 methodologically rigorous studies, Darling-Hammond and colleagues (2017) found that effective professional development for teachers (a) is content-focused, (b) incorporates active and contextualized learning, (c) promotes collaboration, (d) includes models and modeling of effective practice, (e) provides coaching and expert support, (f) offers opportunities for feedback and reflection, and (g) is of sustained duration. These findings are echoed in prior reviews specific to early childhood (Snyder et al., 2012) and early childhood
math (Brenneman, 2014; Zaslow, 2014). Traditional teacher development in the form of intermittent, isolated workshops has been found insufficient to improve teaching and learning (Desimone, 2011; Institute of Medicine, 2015). Coaching can integrate all elements of effective professional development mentioned above (Desimone & Pak, 2017) while being embedded into a teacher’s routines and tailoring opportunities for growth to their specific context.

As a result, coaching has gained popularity as a promising method to improve teaching and learning by the Head Start Performance Standards and other education authorities. Coaches are mentioned 11 times in the U.S. Department of Education’s Every Student Succeeds Act of 2015 (ESSA) which authorizes funding to be used to “hire instructional coaches, or promote teachers who may receive increased compensation to serve as instructional coaches, to support teachers in the development of classroom-based assessments, interpreting assessment data, and designing instruction” (Sec. 1202). ESSA does not name a specific coaching approach, but the description emphasizes using child performance data to guide instruction. Furthermore, the National Institute for Early Education Research’s (NIEER) state preschool quality standards benchmarks added coaching as a requirement for lead and assistant teachers in 2016, explaining “[r]ecent research indicates that coaching focused on improving interactions with children based on feedback from direct observations of teachers can lead to significant improvements in classroom practices and children’s outcomes” (p. 15). They cite research from a variety of coaching approaches and emphasize the importance of “classroom embedded support” (p. 30). Additionally, regulations for publicly funded early childhood education programs in 25 states also require some form of coaching (O’Keefe, 2017). Finally, “mentoring and coaching” are promoted for educators and administrators in the National Association for the Development of Young Children’s (NAEYC) revised statement on Developmentally Appropriate Practice (2020).
“to encourage reflection and continuous learning about the children, families, and communities served” (p. 30). Thus, the field of early childhood education now recognizes a need to move beyond workshops to include contextualized professional support in the form of coaching, but has not specified particulars of how this embedded approach might be most effective.

**Coaching in Early Childhood Classrooms**

In educational contexts, *coaching* broadly refers to a relationship in which an expert works systematically with a classroom educator over multiple points of contact to improve teaching and learning through transfer of knowledge and skills to classroom practice. The term first appeared as an approach to staff development in a 1982 publication by Joyce and Showers, but the literature has yet to reach consensus on a definition of coaching. The practice is also sometimes called mentoring (Chu, 2014; Landry et al., 2009), consultation (Pianta, et al., 2008), expert scaffolding (Kleickmann et al., 2016), performance feedback, advising, technical assistance, curriculum coordination, and intensive professional development (Isner et al., 2011). The coach might be a master teacher employed by a center or school, or an outside individual from a university or other organization. Coaches involved in studies with positive outcomes tend to have higher levels of experience than the average teacher, strong content knowledge, and are skilled in working with adults (Neuman & Wright, 2001; Zaslow, 2014), although many studies do not report coach characteristics.

**Coaching Models**

Programs may develop their own coaching model or be guided by specific approaches. Key features include the coach and teacher engaging together in joint planning, observation, action, reflection, and feedback (Rush & Sheldon, 2005). For example, *Practice Based Coaching* (PBC; NCQTL, 2008) is promoted through Head Start’s Early Learning & Knowledge Center
and focuses on teaching practice in the context of collaborative partnerships. While PBC is content general, *Content-Focused Coaching* (West & Cameron, 2013) focuses on a single subject area and is used by school-based coaches in grades K-8. Both approaches use a cycle of planning meetings, observation, and reflection. Other popular models include: *Cognitive Coaching* (Costa & Garmston, 2002) which emphasizes teachers becoming reflective and autonomous; *Instructional Coaching* (Knight, 2011) which positions the coach as a “dedicated partner;” and *Differentiated Coaching* (Kise, 2006) which adapts coaching to target teacher’s individual personalities and preferences. Kraft and colleagues (2018) place model types into two categories: those that focus on general pedagogical practices versus those that focus on specific content. Their meta-analysis found content-focused approaches to be more effective.

Depending on the approach, context, and needs of individual teachers, coaches engage in a variety of activities in their work with classroom teachers (Killion, 2009) such as observing teaching to collect data, modeling instructional practices, or working directly with students. Coaches might provide material resources, share expertise about a curriculum, or offer emotional support. Outside the classroom they might lead professional learning workshops or partner with administration toward institutional improvement.

**Coaching Outcomes**

Coaching has been found to be a more effective means of teacher professional development than workshops alone. For example, in a randomized control study, Neuman and Cunningham (2009) found that home and center-based providers improved their early childhood literacy knowledge and practice after one year only if they received coursework *plus* coaching. Those who participated in coursework alone were indistinguishable from the control group, which received neither, thus finding strong evidence for the role of coaching in addition to
coursework. A follow up study (Neumann & Wright, 2011) found that coaching alone improved preschool teacher’s literacy practices compared to coursework alone, which was not statistically different from the control group. These studies highlight the unique contributions of coaching, and more research is needed to understand the impact of coaching in preschool math interventions.

Relatedly, studies show that pairing coaching to workshops and/or materials such as curriculum results in greater impact compared to coaching alone (Kraft et al, 2018). In a meta-analysis of 60 studies about a variety of coaching models focused mainly on literacy in contexts ranging from preschool to grade 12 in the United States, Kraft and colleagues found pooled “large positive effects on [teacher’s] instruction and smaller positive effects on [student] achievement” (p. 20). The researchers also found that coaching had a greater impact on student achievement than other school-based interventions including “student incentives, teacher pre-service training, merit-based pay, general [professional development], data-driven instruction, and extended learning time” (p. 27). Coaching is more successful if it focuses on specific content, and when paired with either (a) group meetings such as workshops to build common understanding, or (b) instructional resources and materials such as a curriculum (Gupta & Daniels, 2012; Kraft et al., 2018).

Overall, empirical research on coaching in education has found positive impacts for an assortment of outcomes. These include teaching quality, teacher’s use of a specific practice, teachers’ knowledge, teachers’ attitudes, teacher efficacy, and student achievement (Artman-Meeker et al., 2015; Cornett & Knight, 2009). Particularly in early childhood, coaching interventions have resulted in positive outcomes in the domains of language and literacy (Biancarosa, et al., 2012; Cabell et al., 2011; Hindman & Wasik, 2012; Landry et al., 2009;
Powell et al., 2010), social and emotional learning (Domitrovich et al., 2009; Raver et al., 2008), and quality of teacher and child interactions (Pianta et al., 2008). Notably, two-thirds of causal studies focus on literacy (Kraft et al., 2018), and more research is needed to determine if positive outcomes translate across subject areas.

**Coaching Effectiveness**

At this time, coaching is such a novel topic that most researchers are focused on if it works and have not yet begun to investigate how and why it works. Instead, researchers consider past studies about features of effective professional development in general that coaching can embody. Desimone and Pak (2017) assert that five key aspects of coaching play a role in its success: (a) a specific content-focus; (b) active learning techniques such as discussion and feedback; (c) a sustained duration with multiple points of contact; (d) coherence with standards, curriculum, and daily routines; and (e) collective participation allowing teachers that establishes shared vision and responsibility. Another approach is for researchers to review prior studies about coaching that obtained positive results to seek patterns in the coaching processes. Artman-Meeker and colleagues (2015) identified strategies that were present in 26 studies of coaching in early childhood (birth through age 5) and found that the five most frequently used were: (a) performance feedback from the coach, (b) intentional planning or practice by the teacher between coaching sessions, (c) a written manual, (d) collaborative progress monitoring, and (e) on-going use of an action plan. More research is needed to directly link features and strategies to outcomes.

**Early Math Coaching**

Studies specific to coaching around math in preschool are extremely limited and therefore it is unknown if these promising results about coaching found in prior studies apply to this
context. Coaching is vaguely mentioned as a component of broader, effective math interventions alongside intensive workshops and school-wide support (Brenneman; 2014; Clements & Sarama, 2008; Copley, 2014; Institute of Medicine, 2015). These studies, however, do not focus on the process of coaching or provide details regarding the dosage, model, components, coach characteristics, or involvement of teaching assistants.

**Math Coaching and Workshops**

In a publication about a larger professional development initiative, Chen and McCray (2012) report “on-site coaching” as one of three critical components that led to student learning gains of 3-5 months for Head Start, preschool, and kindergarten children in Chicago Public Schools. The intervention also involved workshops called “Learning Labs” and classroom implementation of common “research lessons.” Coaches are described as veteran teachers trained by project staff but there are no reports of characteristics such as degrees, years of experience coaching, or training to work with adults. The coaching model is described as “an adaptation of Cognitive Coaching” with “planning, observation, and analysis,” but the particulars of the adaptation and details of each component are not expanded upon. While dosage is reported as consisting of three cycles per year for an intensity of “about one hour each,” the published study does not provide details about variation amongst teachers or how dosage may have contributed to outcomes.

**Math Coaching and Curriculum**

In another publication, Germeroth and Sarama (2017) describe coaching in a preschool math intervention called TRIAD (Sarama et al., 2008) that focused on implementation of the *Building Blocks* math curriculum with attention to learning trajectories. In addition to “PD sessions,” the intervention included two types of coaches. “Peer coaches” were teachers involved
in the project who served as leaders within their schools, and “mentors” were experts either from within the schools or the project staff. Mentors visited at least once per month, using a Likert scale fidelity tool to guide observations and discussions. It is unclear if mentors worked with assistant teachers. Findings from mentor logs indicated they played six main roles, listed in order from most to least frequent: (a) observing lessons, (b) intervening to support teachers or students, (c) checking fidelity of curriculum implementation, (d) performing administrative duties, (e) discussing the curriculum with teachers, and (f) providing curriculum-based resources. Children in the intervention group learned more math than those in the control group with an effect size of 0.72 (Clements & Sarama, 2007), although cause cannot be attributed to coaching alone. While strong in capturing coaching activities, the study is limited by the researchers’ inability to examine dosage because mentors spent more time with teachers who demonstrated greater need. It is also difficult to disentangle the impact of the intervention from that of the curriculum. A further limitation is the lack of attention to teacher outcomes, such as shifts in teaching practice, teachers’ knowledge, or teachers’ dispositions.

**Coaching and Math Mediated Language**

In one of the few studies explicitly about early math coaching, Rudd and colleagues (2009) discovered an increase in preschool teachers’ use of “math mediated language” (MML) if they attended a two-hour workshop and received four sessions of “side-by-side coaching” over two weeks, compared to teachers who only attended the two-hour workshop. Coaching consisted of an observation in which the coach took notes about the setting, MML, and missed opportunities to use MML. The coach then met with the teacher to discuss the notes, provide suggestions, and answer general questions and concerns about math in early childhood classrooms. The authors do not give an exact length for observations or meetings other than to
say the coach and teacher “met briefly” (p. 66) and the paired observation and meeting occurred twice within the span of two weeks. The sample consisted of twelve teachers and results are limited to that particular study. Another major limitation is that both teachers working together in the same classroom were observed by the researcher simultaneously, which resulted in a pattern of higher MML frequency for one teacher who was interacting with children and lower frequency for the other who was preparing lessons or performing custodial duties. Thus, research that assesses lead and assistant teachers separately while they are directly interacting with children is needed to accurately capture teaching practice.

**Math Coaching in Grade School Settings**

Beyond early childhood, research focusing on math coaching in elementary and middle school classrooms has demonstrated increased student achievement (Campbell & Malkus, 2011) and shifts in teaching practice (Obara & Sloan, 2009). In particular, working with a coach increases the frequency of active learning formats such as classroom discussions (Race et al., 2002), causes teachers to focus more on interconnected mathematical ideas rather than isolated topics (Becker, 2001), and increases teachers’ use of student work to inform instruction (McGatha, 2009). Similar studies specific to preschool and Head Start populations are needed.

**Conclusion**

In summary, research is clear that better-quality math education is needed in early learning environments. Coaching is a form of professional development that holds potential to improve teaching and learning as demonstrated in early childhood studies from other content areas and math studies in classrooms serving older students. The education research field is just beginning to define more specific attributes of coaching, and additional studies are necessary to supply missing details including coaching models, components, dosage, and coach
characteristics. The current research on effective math interventions does not isolate the process of coaching from other inputs, nor does it consider the effect on teachers’ – especially assistant teachers’ – dispositions and knowledge, which both contribute to shifts in practice. As Head Start centers begin meeting the recent mandates to implement coaching practices, research that illuminates early math coaching and its impact on both teachers and students is crucial.

**Study Objectives and Overview**

The objective of the present study is to understand the process of early math coaching and its impact on lead and assistant teachers in Head Start. A mixed methods design is employed to answer new questions related to an existing study, *Collaborative Math: Creating Sustainable Excellence in Mathematics for Head Start* (McCray et al., 2015) about the Collaborative Math professional development intervention led by the Early Math Collaborative at Erikson Institute. The study will be referred to as *Collaborative Math in Head Start*, and is detailed in the Methodology section of this study. The intervention will be referred to as *Collaborative Math*, and is described in the Theoretical Framework section. The present study had two main objectives:

1. Use existing quantitative data to evaluate the impact of math coaching dosage on Head Start teachers’ and assistants’ practice, content knowledge, and dispositions

2. Conduct new qualitative research, including open-response surveys and content analysis, to strengthen findings and articulate the coaching model in terms of underlying theory, components, coach strategies, and coach characteristics.

Chapter Two presents a review of published literature on coaching, as well as theoretical frameworks and research questions. Chapter Three outlines the methodology including research design, data collection, qualitative analysis, and quantitative analysis. Chapter Four presents the
results from each of the three research questions. Finally, Chapter Five discusses findings, implications, and directions for future research.
CHAPTER TWO

REVIEW OF EMPIRICAL LITERATURE

This literature review is guided by four major questions:

1. What is coaching?

2. How is coaching implemented in schools and early childhood centers?

3. How can coaching improve teaching and learning?

4. How might coaching improve math teaching and learning in preschool?

What is Coaching?

How is Coaching Defined in the Published Literature?

Coaching as a means of teacher professional development is complex due to the variety of names, definitions, and responsibilities that describe a practice that is similar, but not uniform across varying educational contexts. As noted in Chapter One, published research and guidebooks use multiple terms to define coaching. The person doing the coaching has a range of titles including specialist, coach, support teacher, and teacher leader (Campbell & Malkus, 2011). Several authors (i.e. Artman-Meeker et al., 2015; Isner et al., 2011) advocate a need for common language in order for the field of early childhood education to advance. This paper will use the term “coaching” since it is common in the literature, captures the active process, and is one of the original terms.
Where Does the Term Originate?

The Oxford English Dictionary (2018) defines a coach as “an instructor or trainer in sport” and indeed for most the term first conjures images of motivational men standing on the sidelines shouting directives at a team of athletes in action. Opera singers have vocal coaches, corporations employ business coaches, and even expert surgeons benefit from another set of eyes to “observe, judge, and guide” (Gawande, 2011). The dictionary also defines coach as a verb with multiple meanings including “to train or instruct; teach; give (someone) instructions on what to do or say in a particular situation; and give (someone) professional advice on how to attain their goals.” All of these active definitions have relevance to coaching teachers in an education context.

How Did This Term Originate in Schools?

Most accounts credit researchers Joyce and Showers for the popularity of the term “coaching” in education. In a 1982 publication, The Coaching of Teaching, they describe weekly seminars in which eight English teachers at the same high school planned, practiced, and reflected on their teaching together with a peer “coaching partner.” Prior research on teacher training had revealed that teachers only transferred 10% of what they learned in staff development sessions to the classroom. Joyce and Showers hypothesized this new “coaching team” approach would lead to greater implementation and confirmed these results in a series of studies (Showers, 1982; 1984). Costa and Garmson (1994) likely also played a role in the popularity of coaching in education when they created Cognitive Coaching in 1984. Their goal was to change how principals developed their staff by shifting away from a focus on compliance and instead toward a process that encourages teachers to access their own internal thought
process (Ellison & Hayes, 2009). Cognitive Coaching will be explored in more detail later in the section on *popular approaches to coaching in the literature*.

**How Does a Coach Differ from a Mentor?**

In the past, many schools followed a tradition of pairing veteran teachers with new hires or struggling colleagues, mostly to provide emotional support and advice (Ganser, 2002). These experienced teachers are often called mentors, and indeed this practice exists in professions beyond education. What makes coaching different is the shift from one-way mentoring by an expert to a collaborative process that has a specific focus on pedagogy and is guided by a goal-oriented, systemic approach. Although the terms are often used interchangeably, there is some agreement among authors that coaching differs from mentoring. Chu (2014) explains how coaching has a specific focus on the content of teaching such as literacy or math. Neuman and Kamil (2010) contend that coaches may provide emotional support and advice like a mentor, “but their chief role is to help teachers implement new teaching strategies effectively” (p. 266). Coaches also take a more active role, often modeling (Mraz & Kissel, 2014) or co-teaching lessons. Compared to mentoring, which may be general and informal, coaching centers around specific priorities and involves strategic cycles of observations and meetings that are “balanced and sustained” (Neuman & Kamil, 2010, p. 224).

**How has Coaching Evolved?**

In recent years, national concerns about student achievement and teacher quality have further propelled this shift from informal mentoring to formal coaching. At the same time, increasing research on effective professional development has documented the need to move beyond intermittent workshops to improve teaching and learning to include ongoing, contextualized supports (Darling-Hammond et al., 2017; Desimone & Pak, 2017). As a result,
legislators and school officials are beginning to recommend or require coaching as a possible solution. Policy initiatives such as the *No Child Left Behind Act* of 2001 and *Race to the Top Education Grants* as part of *American Recovery and Reinvestment Act* of 2009 recognized the role of high-quality teaching for student achievement, allowing schools to use funding to hire new coaches or modify educators’ existing roles (Campbell & Malkus, 2011; Mraz & Kissel, 2014). For example, educators who previously may have acted as a Math Specialist working with select children in need of extra support might now work with teachers as a Math Coach to broaden their impact (McGatha, 2009). Sudden changes such as this may explain some of the inconsistent terminology and responsibilities.

More recently, the investment in coaches continued with the reauthorization of the *Every Student Succeeds Act* of 2015, which includes 11 instances encouraging the use of coaches. Additionally, *The Improving Head Start for School Readiness Act* of 2017 resulted in the revision of *The Head Start Program Performance Standards* for the first time since 1975. Taking effect in 2017, the section on *Training and Professional Development* (§1302.92) states that as part of a systemic approach to staff development, “A program must implement a research-based, coordinated coaching strategy for education staff.” Since Head Start serves about one million children in 60,000 classrooms per year, this means a significant influx of coaches into early childhood settings. Furthermore, the National Institute for Early Education Research (NIEER) has produced state preschool quality standards benchmarks that recommend coaches for both lead and assistant teachers in state-funded preschools (Barnett et al., 2017). Finally, publicly funded early childhood education programs in 25 states require coaching, and many state-run Quality Rating and Improvement Systems, designed to increase quality and access to early care
and education, employ coaches (O’Keefe, 2017). In each case, who serves as this coach varies across legislative requirements and the needs of each unique context.

**Who is the Coach?**

Individuals who have the professional title “Coach” are a diverse group. Coaching roles are closely tied to funding. Therefore, a position may be ongoing and built into a school’s regular budget, or short-term as part of a temporary professional development initiative. In a review of 46 studies, Isner and colleagues (2011) found that coaches in early childhood programs were nearly all female, had education credentials, and were formerly classroom teachers. Some studies prioritized experience as a director and some required experience working with adults. Overall, coaches in the literature tend to have higher levels of experience than the average teacher, strong content knowledge, and are skilled in working with adults.

As described above, some coaches are former teachers based in schools who transitioned out of the classroom to work only with adults. In other settings, coaches have a hybrid position, working with children for part of the day and relieved of those responsibilities to coach adults during others. And in other settings, a designated “Teacher Leader” may teach children full-time and provide coaching before and after the school day or during common planning periods (Germeroth & Sarama, 2017; Obara & Sloan, 2009). Depending on school size, school-based coaches might work with all teachers in the school or those from a select grade level or grade band. Others are district-employed coaches who may visit multiple school sites. In some cases a principal, center director, or other administrator may take a coaching role. Experts advise the need to keep management and coaching separate (Aiken & Akers, 2011; Jablon et al., 2016) “because the implicit threat of a negative evaluation could reduce educators’ trust and openness to feedback from their coach” (O’Keefe, 2017, p. 21). Budget and time limitations often make
combining these roles necessary, however, and efforts can be taken to keep conversations about compliance and job responsibilities separate from coaching meetings that focus on relationships, data discussions, reflection, and goal-setting.

Coaches in schools may also be fellow colleagues in the same or similar role who partner to provide reciprocal support. Research has found mixed results regarding the effectiveness of peer coaching on improving teaching and learning (Ackland, 1991; Jao, 2013; Joyce & Showers, 2002; Murray et al., 2008; Truesdale, 2003) noting strengths in affordability and shared teacher responsibility, but weaknesses due to insufficient support systems and accountability. Furthermore, many definitions highlight the coach as being someone with content expertise and skill in working with adults (Neuman & Wright, 2010; Zaslow, 2014), which is not the focus of generalist, full-time classroom teachers.

Beyond schools, coaches might be an expert from a university partner including trained staff, research associates, and professors (Cave & Brown, 2010; Herron, 2010). These coaches are often connected to wider professional development initiatives and may or may not be part of an empirical research study (Artman-Meeker et al., 2015). A coach might also be employed by another organization, such as a non-profit focused on literacy or a medical facility promoting health in schools.

Lastly, some coaching models use a practice called self-coaching in which a teacher acts as both coach and coaching recipient (Bishop et al., 2015; NCQTL, 2008;). Using self-guided materials to structure reflection, a teacher watches videos of themselves teaching a lesson. The process might also involve using tools designed to assess effective teaching practices to evaluate their progress, or an online tutorial to assist teachers in planning. In fact, the use of video is becoming increasingly popular as one mode of coaching.
What are the Different Modes of Coaching?

Coaching may occur physically on-site, or may occur remotely with the aid of digital technology, or through a combination. Even before COVID-19, virtual coaching had been used by psychologists and medical doctors and was gaining popularity to improve teaching (Mraz & Kissel, 2014). For example, nurses may virtually check-in with patients in between office visits to guide their medication management and lifestyle choices (Goessens et al., 2008). In education, teachers record videos of themselves teaching a lesson and then mail or upload the footage. A remote coach, also known as a distance, virtual, or online coach, watches the video and provides feedback via either a written response, telephone call, video chat, or on a split-screen platform that simultaneously shows the video and allows them to pause and comment (Lee et al., 2012; Powell et al., 2010; Pianta et al., 2008; Sherin & Han, 2004; van Es & Sherin, 2008). Technology may have affordances in reducing cost and travel time, thereby increasing access to coaching especially for teachers in rural communities, but may also require additional technical support. More research is needed as this type of coaching grows in tandem with the increasing popularity of digital learning.

Who is Being Coached?

Who participates in coaching also varies within the education literature. Coaching may be required for all teachers at a school or site, voluntary for those interested, or targeted to select teachers. For example, the regulations on coaching in Head Start require programs to identify and work with teachers most in need of support (§1302.92). While this may be necessary to maximize limited resources, it can also result in attaching a negative stigma to coaching as remediation rather than a practice from which all teachers can benefit. In some cases, a single teacher may work with more than one coach if the school is involved in multiple professional
development initiatives at the same time. For example, a teacher might meet monthly with three different coaches over the course of a school year: a literacy coach from a non-profit organization, a math coach from a university helping to implement a new curriculum, and a veteran Teacher Leader from the classroom across the hall.

Most coaching approaches involve one-on-one meetings, whereas some involve multiple practitioners meeting as a group. Meetings may include co-teachers, assistants, and paraprofessionals who work in the same classroom (i.e., Raver at al., 2008), or grade level teams with teachers coming together from multiple classrooms. Advocates of group coaching find that it builds consensus around effective teaching practices and motivates teachers to follow through. Meeting together with the coach all at once also helps ease the demands of limited time, but may also cause complications if all adults must leave the classroom at once and an additional adult is needed to supervise children. Group coaching may also be limited in targeting individual teachers’ needs. More research is necessary on the affordances and challenges of group coaching (Brown & Grant, 2010; Fettig & Artman-Meeker, 2016; Kazemi & Franke, 2004; Sherin & Han, 2004; van Es & Sherin, 2008).

Finally, some coaching models include leaders, such as principals and center directors. For example, in Collaborative Math, instructional leaders are present during coaching sessions with teachers, and participate in extra meetings with coaches in order to reflect on the coaching process and eventually take over to sustain the work after the project concludes. Research on effective professional development programs highlights the importance of including those in influential positions (Zaslow, 2014) in teaching training efforts, but their involvement in coaching specifically is rarely reported and under-examined (O’Keefe, 2017).
Overall, a meta-analysis of coaching studies in Head Start centers found that lead teachers were recipients of coaching most often (76%). Paraprofessionals and teaching teams did participate, but less often (25%) than lead teachers (NCQTL, 2008). Whether these meetings were as a group or one-on-one is unclear. Since the majority of published studies focus on classroom teachers, more research is needed to examine the impact of coaching on instructional leaders and assistant teachers, especially in early childhood settings.

**What is the Role of a Coach?**

Part of the difficulty in outlining what coaches do is that the nature of the work changes depending on the goals, guiding framework, school context, needs of the educators, administrator expectations, time of the school year, experience level of the coach, and other variables. Within the literature, authors outline multiple responsibilities for a single coach, and Killion (2009) provides perhaps the most comprehensive list of 10 “roles” which are summarized below. A coach may play many of these roles at once, and may play some never at all:

- **Data Coach** – help teachers understand data and plan instruction using it
- **Resources Provider** – share research findings and teaching tools
- **Mentor** – serve the needs of new teachers, acclimate teacher to school’s professional norms, practices, and policies
- **Curriculum Specialist** – focus on what is being taught
- **Instructional Specialist** – focus on how material is taught
- **Classroom Supporter** – co-planning, co-teaching, observing, reflecting with the teacher
- **Learning Facilitator** – lead professional development, team meetings
- **School Leaders** – contribute to school wide reform initiatives
• **Catalyst for Change** – ask questions, instill curiosity, raise doubts, and generate dissonance to promote change

• **Learner** – seek continuous development and reflect on their work with teachers

The complex role of a coach is also accompanied by challenges noted in the literature. These include skillfully integrating multiple modalities (such as lesson planning, co-teaching, and debriefing), understanding and addressing the growth of teachers, collaborating with administrators, transitioning from working with children to working with adults, balancing multiple responsibilities and ambiguity, understanding and negotiating school culture, and setting priorities within time constraints (Campbell & Malkus, 2011; West & Staub, 2003). Coaches must also cultivate awareness of factors influencing their decision-making and relationships with teachers including their own identity and how this differs from the teachers and students, as well as the social political context in which they work (Young, 2019). Otherwise, misunderstandings can impede a coach’s effectiveness. Thus, cultural competency plays an important role in coaching, and there is a need to identify coaches who understand the communities in which they work (Chu, 2014).

**How are Coaches Trained and Supported?**

In order to overcome these challenges, coaches need training and support. This element is especially under-documented in research publications (Downer et al., 2009; Germeroth & Sarama, 2017; Snyder et al., 2012). Among published research focused on birth through age five, Artman-Meeker and colleagues (2015) found only 55.1% of studies listed the preparation or support strategies for coaches. Most commonly coaches attended an initial training event and followed a protocol to conduct their coaching sessions with teachers (28.6% of studies). Other
studies implemented peer support structures (18.5%) such as monthly meetings or direct supervision (18.4%).

Several studies suggest that the success of coaching relies on the expertise of the coaches (Campbell & Malkus, 2011; Garet et al., 2008; Germeroth & Sarama, 2017; Mraz & Kissel, 2014). For example, Campbell and Malkus (2011) explain that coaches in their study participated in intensive coursework on math content, pedagogy, and coaching approaches and therefore their positive findings should not be generalized to coaches with less expertise. Programs that require coaching may not achieve the results they intend if they do not take the time to ensure that coaches are properly trained and supported. Research highlights the importance of interpersonal skills, understanding of adult learners, mastery of successful coaching techniques, and knowledge of the content and effective strategies to teach students, and clear roles and responsibilities. Some states have begun coaching certification programs (O’Keefe, 2017) and universities such as Northwestern University and Columbia University offer coursework on Instructional Coaching. Future research efforts will improve contributions to the field by including information regarding the credentials of the coaches involved in their studies and how they were trained and supported.

Why is Defining Coaching Important?

In practice, it may be useful to explicitly define the role of a coach so that everyone involved in the work has the same understanding. This also allows the coach to best use their limited time and determine which of the ten roles described above (Killion 2009) is most necessary in the moment (Obara & Sloan, 2009). An undefined role can lead to mistrust and confusion among coaches, teachers, and administrators. In a study where coach roles were not explicitly defined, Poglinco and colleagues (2003) found that the teachers perceived coaches to
be informants for the administrator rather than colleagues. Furthermore, teachers may need advice for how best to work with a coach (Yopp, et al., 2011), and assurance that coaching is not a punishment but can benefit all professionals (Gawande, 2011). In research, coaching must be defined so that scholars can be sure they are discussing the same set of activities rather than convoluting concepts.

**How is Coaching Implemented in Schools and Early Childhood Centers?**

Just as roles differ across contexts, so do approaches to coaching. An approach refers to the way coaches conceptualize their work and the perspectives that guide their decisions. Coaching approaches can be as informal as a collection of ideas or as formal as a research-tested model. Multiple reviews of the published literature highlight a need for researchers to describe their conceptual frameworks in more detail (i.e., Isner et al., 2011; Tout et al., 2011). One review focused on coaching in early childhood settings found that only two of the 49 studies contained a clear coaching model (Artman-Meeker et al., 2015). Detailed descriptions of coaching approaches are more often found outside the empirical literature in published guidebooks, and future research must test the variance among these options. Coaches, especially those working individually in schools with less oversight, often craft their own approach by drawing from these sources and adapting them to their unique setting. In many cases, school-based coaches find themselves in a new coaching role with little training and turn to books written to provide guidance for coaches. Select approaches including Instructional Coaching, Content-Focused Coaching, Cognitive Coaching, Differentiated Coaching, and Practice-Based Coaching are summarized below. This is by no means an exhaustive list of approaches, but a sampling of some of the conceptualizations that arise frequently in publications.
What is Instructional Coaching?

Knight (2009) is one of the leading voices on coaching in education, with numerous publications and a prominent coaching institute. He defines the role of the instructional coach as a person who “…partners with teachers so they can choose and implement research-based interventions to help students learn more effectively” (p. 31). Knight emphasizes seven principals for this partnership:

1. *Choice* – coaches should offer teachers choices
2. *Voice* – teachers should be able to express their point of view and coaches work to help them find their voice, not to make them think a certain way
3. *Dialogue* – coaches and teachers learn together in equal conversation
4. *Reflection* – coaches provide teachers with enough information so that teachers can consider ideas before adopting them
5. *Praxis* – meaning arises when both partners reflect on ideas and put them into practice
6. *Reciprocity* – coaches learn alongside teachers

Knight advises coaching sessions to focus on classroom management first, believing this must be in place before moving on to other goals such as teachers’ subject matter knowledge and the best form of instruction to convey it to students. Understanding if students are mastering the content through formative assessment is another important focus of coaching.

Knight (2018, 2020) defines the approach of Instructional Coaching as “dialogical coaching” which falls between the two extremes of “facilitative coaching” and “directive coaching.” In facilitative coaching, coaches work from the assumption that the teacher knows what to do and the coach acts as a “sounding-board” to help the teacher reflect and make decisions without giving direct feedback. In the opposite approach, directive coaching, coaches
work from the assumption that the teacher does not know what to do and the coach acts like a “mentor to an apprentice” to explicitly advise teaching practices and make sure they are implemented. Situated between these opposing approaches, dialogical coaching positions the teacher as the decision-maker and coaches indirectly offer their expertise. “Dialogical coaches balance advocacy (telling) with inquiry (asking),” explains Knight (2020, p. 1). He also admits that striking this balance is “easier said than done.”

Instructional Coaching follows an “impact cycle” of (a) identifying, (b) learning, and (c) improving (Knight, 2018). Identifying includes examining video of a classroom episode, student assessment data, and interviews with students, or samples of student work to determine a focus for coaching. Teachers then set a “PEERS goal: Powerful, Easy to achieve, Emotionally Compelling, Reachable, and Student-focused.” Next, in the learning stage, teachers study a new strategy by using checklists and examples such as watching a video of another teacher, observing another teacher in person, or seeing the coach model the strategy. Lastly, in the improvement stage, teachers try out the new strategy in their classroom and make modifications.

**What is Content-Focused Coaching?**

Math coach and author Lucy West (2009) defines Content-Focused Coaching as “an iterative process centering on thoughtful lesson design, skilled enactment of lessons, reflective analysis of student learning, and use of the analysis to construct ensuing lessons” (p. 115). In contrast to other forms of coaching, content is viewed as the critical aspect and coaches must be immensely knowledgeable of appropriate instructional strategies, student development trajectories, common student misconceptions, and assessment methods in their particular discipline such as reading, math, or science. West also conceptualizes the coach as a bridge between administrators and teachers who can use their leadership potential to ask hard questions
that change systems and promote equity (West & Cameron, 2013). In order to successfully connect with others, coaches must first recognize their own biases and work to equalize power in meetings with teachers. Content-Focused Coaching consists of: (a) a pre-conference where the coach and teacher design the lesson together; (b) the lesson where either the teacher teaches, the coach teaches, or teacher and coach co-teach; and (c) a post-conference where teacher and coach discuss student learning and reflect on the lesson. Another difference in this approach is the importance given to the pre-conference whereas other models lack this component or place greater importance on the post-conference. “Planning,” argue West and Staub (2003), “has the most potential to affect practice deeply.” They explain that during planning the coach works with teachers on key aspects of lesson design including “helping teachers understand the content they teach, how children learn that content, how to craft questions when conferencing with students, how to anticipate and support student learning in the classroom, and how to assess student learning” (p. 96). Based upon their experience, West and Staub contend that in order for Content-Focused Coaching to gain momentum and display measurable results, three to five years are needed.

What is Cognitive Coaching?

Costa and Garmston (1994; 2002) trademarked Cognitive Coaching, a process in which coaches see themselves as mediators of thinking and enter conversations with less of an agenda than other forms of coaching. As mentioned earlier, the technique was originally developed to shift principals from a behaviorist approach of giving teachers directive feedback focused on compliance, to a constructivist approach that supports teachers’ own thought processes and allows them to be more self-directed in their growth (Ellison & Hayes, 2009). Cognitive Coaching draws on the work of researchers to establish a conceptual framework called “Five
States of Mind.” These include efficacy, consciousness, craftsmanship, flexibility, and interdependence. The framework also includes four metaphorical orientations used by the coach: parent, mediator, friend, and boss. Cognitive Coaching has been the subject of numerous studies suggesting its positive effects on student test scores, teacher efficacy, teacher job satisfaction, and teacher collaboration (Edward, 2005), but more rigorous research with randomized control designs is needed (Knight, 2009).

**What is Differentiated Coaching?**

Another approach called Differentiated Coaching (Kise, 2006) emphasizes the individual needs of the teacher in the coaching relationship. Coaches are advised to use Myers-Briggs Type Indicators, (extraversion vs. introversion, sensing vs. intuition, thinking vs. feeling, and judging vs. perceiving) to assess teachers’ personalities and individualize coaching. Kise explains, “There are clear differences in the kind of information people with different personalities and learning styles need, how they process that information, and what makes change most stressful. Resistance to change increases when those needs are not met” (p. 148). Kise argues some teachers require a more directive approach with the coach acting as an expert, where others benefit from a more collegial mentor. Under this approach, a coach should hypothesize a teacher’s style, ask questions to discover their beliefs, and identify the problems the teacher wants to solve in order to develop a coaching plan. There does not appear to be any research on the effectiveness of Kise’s Differentiated Coaching approach.

**What is Practice-Based Coaching?**

Practice-Based Coaching (PBC; see Figure 1) is specific to early childhood and differs from other models in its explicit focus on teaching practices (Snyder et al., 2015). It is a three-step, cyclical process that includes: (a) “Planning goals and action steps;” (b) “Engaging in
focused observation;” and (c) “Reflecting on and sharing feedback about teaching practices” (NCQTL, 2008). PBC emphasizes a “collaborative partnership” in which teachers feel safe to ask questions, discuss problems, and try new ideas. This approach was originally used to support preschool teachers of children who are at-risk for disabilities to implement social-emotional, behavioral, and instructional teaching practices with fidelity. In PBC, the coach can be an “expert,” “peer,” or “self,” and coaching can occur on-site or virtually. The model also includes a group coaching format called Teachers Learning and Collaborating (TLC). Multiple teachers gather together to view videos of their practice and a coach facilitates reflective group discussion. The National Center on Quality Teaching and Learning (NCQTL), headed by the U.S. Department of Health and Human services, has chosen to formally promote and train Head Start teachers in PBC (NCQTL, 2008). It has also been explicitly described in the literature and tested in a number of studies (Artman-Meeker et al., 2015; Snyder et al., 2015).

Figure 1. Key Components of the Practice-Based Coaching (PBC) Framework (Snyder et al., 2015)
How Do These Approaches Compare?

A noted difference among these approaches is what each suggests is the goal of coaching. Content-Focused Coaching emphasizes increasing teachers’ pedagogical content knowledge (Shulman, 1986), or the content knowledge needed for teaching, Practice-Based Coaching focuses on teaching practices, and Differentiated Coaching targets teachers’ individual personalities. Cognitive Coaching and Instructional Coaching branch across all three of these aspects, with the former aiming to help teachers become more reflective and thus autonomous in their development, and the latter emphasizing the coach and teacher partnership as the key ingredient in the change process. Indeed, many organizations (i.e., George Lucas Foundation) and researchers (O’Keefe, 2017; Desimone & Pak, 2017) use the term “instructional coaching” likely because it is broad and the name suggests improving instruction as the goal of coaching. It is unclear if their use always refers to Knight’s philosophy. In many cases it appears to be a convenient umbrella term to refer to coaching in education. There may be a benefit, however, to coaching having an explicit focus (Kraft et al., 2018) and more research is needed to test the strengths and weaknesses of approaches across differing contexts. Table 1 summarizes the approaches described above, the authors associated with each, and the focus that differentiates them from other types of coaching.
### Table 1. Summary of Coaching Approaches Found Within the Education Literature

<table>
<thead>
<tr>
<th>Approach</th>
<th>Associated Authors</th>
<th>Focus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instructional Coaching</td>
<td>Knight</td>
<td>coach and teacher partnership as the key ingredient in the change process</td>
</tr>
<tr>
<td>Content-Focused Coaching</td>
<td>West, Cameron, Staub</td>
<td>increasing teachers’ pedagogical content knowledge</td>
</tr>
<tr>
<td>Cognitive Coaching</td>
<td>Costa, Garmston, Ellison, Hayes, Edwards</td>
<td>help teachers become more reflective and thus autonomous in their development</td>
</tr>
<tr>
<td>Differentiated Coaching</td>
<td>Kise</td>
<td>adapt coaching to targets teachers’ individual dispositions</td>
</tr>
<tr>
<td>Practice- Based Coaching</td>
<td>Snyder, Hemmeter, Fox, Artman-Meeker, Fettig</td>
<td>collaborative partnership to improve teaching practices</td>
</tr>
</tbody>
</table>

Another way to compare these and other coaching approaches is to think of them along a continuum from more reflective to more directive (Sandefur et al., 2014) or in Knight’s (2020) words “facilitative” and “directive.” For example, Cognitive Coaching is more reflective since the emphasis is on mediating teachers’ thinking about their practice, whereas Content-Focused Coaching is more directive, relying on specific data collected during observations. This is not to say that either reflection or direct feedback is absent from some approaches, but that it is less frequent. Cognitive coaches likely require greater training in questioning techniques, whereas Content-Focused coaches need strong understanding of subject matter and teacher-student interactions. Cognitive Coaching may have benefits in allowing the teacher to drive their change and continue improving in the absence of their coach, whereas Content-Focused Coaching may be a more efficient process.
What Other Coaching Approaches Exist?

This section summarized five of the main approaches to coaching in education found in the published literature. Other models in early childhood include relationship focused coaching (Chu, 2014), powerful interactions (Jablon et al., 2016), self-reflection (Rush & Sheldon, 2011), and diagnostic/prescriptive (Neuman & Wright, 2010). Coaching supports are also often subject specific, and several books exist to guide math coaches working with teachers in K-12 (Hansen, 2016; Bay-Williams & McGatha, 2014; Hull, Balka, & Miles, 2009). At this time, there are no books or frameworks about coaching that specifically cover both preschool and math. Many schools, programs, and individual coaches merge ideas from multiple coaching approaches, whereas others are less deliberate in choosing a defined approach to guide their coaching.

What are the Components of Coaching?

Defining the coaching approach ultimately may depend on the goal of the coaching intervention. While generally related to improving teaching and learning, the goal may be rooted in a specific focus such as a content area, curriculum, or teaching quality assessment tool. Reaching this goal, and the resources available for doing so, might require differences in coaching cycle components and dosage. During coaching sessions, teachers and coaches might engage in a variety of strategies, and outside of sessions teachers may participate in additional, related professional development activities. Each of these components including focus, parts, and dosage will be explored in detail below.

What is the Focus?

Coaching interventions may be open-ended, or focus on implementation of a new curriculum, a specific content area, or tools to assess teaching practice. In a review of 101 studies of coaching in preschool, “pre-academic skills” were the most common focus (43%) followed by
“social-emotional development” (36%), and “communication skills” (22%). Coaching that did not have a specific focus occurred in a quarter of the studies, and topics such as family-centered practice, motor skills, and inclusive practices were reported least often (NBDCI, 2008).

When implementing a new curriculum, teachers can benefit from a coach who is more experienced with the materials and their scope and sequence. For example, math coaches from the University of Chicago provide workshops and coaches to help PreK-6 classrooms adopt the *Everyday Mathematics* curriculum (McGraw-Hill Education, 2016). Some published curriculums come with a coaching guide, such as *Creative Curriculum* (Teaching Strategies, LLC, 2015) used in preschools. Coaching in a curriculum context may focus more on fidelity to the curriculum, whereas Content-Focused Coaching supports teachers in understanding the subject area and pedagogical approaches.

Coaching may also be guided by standards such as *Common Core State Standards* (National Governors Association Center for Best Practices, Council of Chief State School Officers, 2010) and concepts identified through student test scores as needing improvement. In regard to content areas, literacy coaching is by far the most common in early childhood, dominating the empirical literature (i.e., Algozzine et al, 2011; Powell et al., 2010; Hindman & Wasik, 2012; Landry et al., 2009; Neuman & Cunningham, 2008; Stover et al., 2011; Wasik & Hindman, 2011). Early childhood coaches also focus on social and emotional learning (SEL; i.e. Raver et al; 2008) as well as interventions combining SEL and literacy (Domitrovich et al, 2009). Of note, early math is absent from overviews of coaching in early childhood (i.e., Mraz & Kissel, 2014) and only the focus of a few studies in the empirical literature (Germeroth & Sarama, 2016; Rudd et al., 2009).
Alternatively, coaching may focus on teacher-student interactions, instructional practices, or global quality as measured by tools to assess teaching practice such as Teachstone’s Classroom Assessment Scoring System (CLASS; Downer et al., 2009; Kinzie et al., 2006; Pianta et al., 2008), the Early Childhood Environmental Rating System (ECERS; Isner et al., 2011), Charlotte Danielson’s Framework for Teaching (Knight, 2009), and the Teaching Pyramid Observation Tool (TPOT; Fox et al., 2011). In each one of these instances, coaches first conduct a needs assessment using the rating system from the tool and then target coaching sessions to focus on specific domains or dimensions. This approach is intended to provide observation data to compare to research-supported teaching practices; it is not meant to be evaluative.

Studies have begun to examine the benefits and disadvantages of the different coaching foci. In their meta-analysis of 60 coaching studies, Kraft and colleagues (2018) found that coaching is more successful if it focuses on specific content rather than being open-ended. In a study of literacy interventions for “at-risk” preschoolers, Landry and colleagues (2009) found that not requiring teachers to use a specific curriculum allowed greater participation and more individualized mentoring, yet it also put teachers with weak curriculums at a disadvantage. After a study that combined the Building Blocks math curriculum and Tools of the Mind social-emotional curriculum did not produce the same positive results as the math curriculum alone had in the past, Germeroth and Sarama (2017) hypothesize that coaching might be more successful if focused on one domain. More research is needed to understand the role of the coaching focus in impacting teacher growth.

**What are the Parts of a Coaching Cycle?**

In general, a coaching cycle has three parts harkening back to Joyce and Showers’ original approach. The first point of contact may be called a planning meeting or pre-conference
and usually involves some form of goal setting for the upcoming lesson. The second is the lesson or observation where the coach visits the teacher’s classroom either in person or by watching a video. The third piece of a coaching cycle is referred to as a reflecting meeting, post-conference, or debrief.

Importantly, not all coaching approaches include all three parts. For instance, West’s Content-Focused Coaching purports that the planning is most important, whereas Griffiths and Campbell (2009) omit this component. Interestingly, when a peer teacher acts as the coach, Showers and Joyce (1996) have decided it is better to skip the post-conference since it hinders collaboration. The timing of when these components occur, such as immediately following or with multiple days in between is rarely explained in the literature and may vary across coaching relationships due to logistical constraints. More research is needed to understand this and the impact of the different components.

What is the Dosage of Coaching?

The coaching dosage includes the span of time over which the coach visits (duration), how often (frequency), and for how many minutes or hours at a time (intensity). Many published studies do not report this information. In those that do, the duration can last anywhere from one week to five years, with the majority spanning a single academic year and lasting about eight months. The frequency of coaching found within the literature ranges from one coaching session total, to three coaching sessions per week, and occurs monthly on average. Intensity is most noticeably absent from the literature. In studies that do report, averages range from 30-90 minutes per cycle component (Snyder et al., 2015; Isner et al, 2011; NCQTL, 2008). The nature of schedules within schools and a teacher’s individual needs means that dosage may vary even
among participants within the same study. Interruptions are also common and securing both time and a quiet space is a challenge (Brenneman, 2014).

West and Staub (2008) suggest that from their experience, coaching initiatives generally take three to five years to gain sustainable momentum and show measurable results. In a randomized control study, Campbell and Malkus (2011) found that highly trained math coaches positively affected student achievement in grades three through five after a three-year intervention, but these results were not evident at the conclusion of the first year. The more ambitious the goal, the greater the dosage required, but this is also more expensive and time consuming (Zaslow, 2014). Additionally, the planned dosage may not result in the actual dosage due to logistical complications. Tracking this information requires systems such as coaching logs and often relies on coach self-report. Programs that include coaching will benefit from research that systematically studies duration and includes follow-up to ascertain if impacts are sustainable.

**What Strategies Do Coaches Use?**

During these visits, coaches employ a variety of supportive strategies to help teachers reach the specific goals of the intervention. Identifying coaching strategies is challenging since the decisions coaches make in the moment unfold organically along with the teacher’s needs, and the optimal technique depends on the objective at hand. Additionally, strategies fluctuate throughout the duration of the coaching relationship. For example, coaches might focus more on building relationships and conducting needs assessment in the beginning, then shift to reflection and goal setting in later coaching cycles. Researchers may analyze coaching logs to code for common strategies, but the literature has yet to standardize the language used to describe the techniques coaches might use, let alone examine their impact. Many studies do not provide these
details and additional research is needed to unpack strategies used in coaching to understand their impact on shifting teaching practice.

Specific to early childhood, Artman-Meeker and colleagues (2015) provide a comprehensive overview of coaching strategies in their analysis of 49 studies on coaches working in classrooms with teachers of children birth to age seven. The research team drew from previous reviews (Snyder et al., 2012) and early childhood coaching resources (Chu, 2014; Rush & Sheldon, 2011) to identify 12 “strategies.” These are listed in Table 2 in order of frequency at which Artman-Meeker and colleagues clearly identified the strategy in a study, and described using the authors’ words. Overall, performance feedback was the most frequent while self-reflection, relationship building, and role-play were infrequent. This suggests that coaching in early childhood may be more directive and less collaborative.

Additionally, the National Center on Quality Teaching and Learning (2008) included strategies and their frequency in a review of 101 studies on sustained and focused coaching support provided to early childhood practitioners. Similarly, the researchers found performance feedback the most frequent strategy, occurring in 72% of the reviewed studies. They further divided this feedback by format into verbal (64%), written (24%) and graphed (7%). The next most frequently documented coaching strategy was modeling (45%), and it was unclear if this was live, video, or both. Other strategies included engaging in a problem solving discussion (30%) similar to Artman-Meeker and colleagues’ action plan, in-situ support (8%) provided within the classroom, and role-playing (4%).
Table 2. Frequency of Strategies Used by Coaches Working with Teachers of Children Ages 0-7 (Artman-Meeker et al., 2015)

<table>
<thead>
<tr>
<th>Coaching Strategy</th>
<th>Description</th>
<th>Frequency (n = 49)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance feedback</td>
<td>Coach provides feedback based on observation of teacher implementation (checklists, face-to-face protocols, e-mail, newsletters, and annotated videos)</td>
<td>85.7%</td>
</tr>
<tr>
<td>Intentional planning or practice between sessions</td>
<td>There are clear plans for opportunities for teachers to work on new skills in between coaching visits</td>
<td>55.1%</td>
</tr>
<tr>
<td>Using a manual</td>
<td>Manual or written directions are used as a guide to support teachers during coaching</td>
<td>53.1%</td>
</tr>
<tr>
<td>Collaborative Progress Monitoring</td>
<td>Teacher and coach work together to track teacher’s progress on practices learned throughout the study</td>
<td>38.8%</td>
</tr>
<tr>
<td>Ongoing use of action plan</td>
<td>An action plan is mentioned and followed throughout the coaching sessions/study</td>
<td>32.7%</td>
</tr>
<tr>
<td>Practice New Skills</td>
<td>There is an explicit description of opportunity for teachers to practice new skills during coaching/observation sessions</td>
<td>30.6%</td>
</tr>
<tr>
<td>Live Modeling</td>
<td>Coach models specific strategies during coaching session</td>
<td>26.5%</td>
</tr>
<tr>
<td>Help with instructional materials</td>
<td>Coach helps teachers in preparing materials needed to implement newly learned skills</td>
<td>20.4%</td>
</tr>
<tr>
<td>Video Modeling</td>
<td>Use of videos to model specific strategies as a way of instruction during coaching</td>
<td>16.3%</td>
</tr>
<tr>
<td>Self-reflection</td>
<td>Teacher reflects on practices</td>
<td>14.3%</td>
</tr>
<tr>
<td>Intentional Focus on Relationships</td>
<td>Coach spends part of coaching time building relationship with teacher</td>
<td>12.2%</td>
</tr>
<tr>
<td>Role-play</td>
<td>Coach and teacher take on roles to practice strategies (e.g., coach takes on the role of the teacher to show specific strategies)</td>
<td>4.1%</td>
</tr>
</tbody>
</table>

Finally, of the little that is known about coaching strategies, there is some evidence suggesting the importance of coaches taking an active role rather than passively observing by using strategies such as modeling, co-teaching, and real-time feedback (Fox et al., 2011; Neuman & Cunningham, 2008). Other coaching strategies included in studies with positive outcomes include deliberate goal-setting (Neuman & Cunningham, 2009; Skiffington et al., 2011) and
facilitating reflection that engages the teacher in problem solving (Guiney, 2001). More research is required to determine whether or not these strategies had a direct impact on outcomes.

**What Other Activities Might Accompany Coaching?**

Coaching is often located within the context of a larger educator professional development (PD) initiative with other related activities. Some researchers have found positive impacts from coaching alone (McGatha, 2008), whereas others advocate the need for coaching to move away from one-on-one meetings to impact school culture and whole system reform (Fullan & Knight, 2011). Of the 44 early childhood studies reviewed by Isner and colleagues (2011), all but six included related activities. The most common is typically referred to as “training” which includes workshops often known as “PD sessions” during which an instructor guides a group of teachers to increase content knowledge. These may occur only before coaching begins, or may continue in-between coaching cycles. In some cases the coach facilitates these workshops, whereas in others they are led by another expert. Teachers might also participate in college coursework, which is more intensive than training and earns credit toward a degree.

Another possible practice is establishing professional learning communities (PLCs) where groups of teachers meet regularly to collaborate. A coach may or may not be present. During PLCs teachers may look at student work, assessment data, videos of teaching, or other materials to promote reflection and determine action steps. Book clubs are another approach, with teachers gathering to discuss assigned chapters relating to the professional development initiative’s topic. Readings may also be assigned individually with less accountability. Finally, teachers may be motivated by participating in a school initiative to embark in individual professional development such as viewing online resources or conducting action research in their classroom (Desimone, 2011). Outside of these formal activities, informal learning may occur
such as two teachers trading advice while at the copy machine or group discussions in the teacher’s lounge. Involving the entire school makes this additional learning more likely to occur. Research on effective math professional development in early childhood has found that school-wide participation, including leaders, is a necessary component (Brenneman, 2014).

**How Can We Summarize the Complexity of Coaching?**

While coaching has many variables, there are a few overarching commonalities that emerge from the complexity of coaching as it is described in the education literature. These include supporting teacher growth, embedded and individualized support, and a systematic process that encourages teacher self-reflection.

**Supporting Teacher Growth**

First, the purpose of coaching is to support teacher growth with the ultimate aim of enhancing student learning. A coach differs from a supervisor who evaluates and checks for compliance. Instead, coaches help teachers identify specific goals to improve their practice and the relationship focuses on how to achieve them. The goals may be general, or they may be specific to a content area, a new curriculum, or a tool to assess teaching.

**Embedded and Individualized**

Secondly, coaching differs from other forms of professional development because it is embedded in the existing school context and routines. The relationship is also tailored to meet a teacher’s needs. Coaching involves another individual visiting a teacher’s classroom, either in person or remotely through video. What the coach does during this visit ranges from observation, to co-teaching alongside the teacher, to modeling a lesson as the teacher watches.
**Systemic and Reflective Process**

A third commonality is a systematic approach with multiple points of contact, usually in the form of meetings. These may occur before a classroom visit, after a classroom visit, or both. Each cluster of meetings around a classroom visit may be referred to as a coaching cycle. During these meetings, coaches typically ask questions to engage teachers to self-reflect on their practice (although this appears less frequent in early childhood, as noted above). Coaches might use other strategies such as having teachers rehearse the lesson in role-play, or sharing data collected during the visit. Records such as coaching logs are often used to help keep track of teachers’ action plans and progress toward goals.

As a result of their extensive literature review, Isner and colleagues (2011) recommend all coaching interventions develop a coaching manual that addresses the purpose of coaching, the foundational philosophy and research base, coaching activities, expected knowledge and skills, dosage, duration and intensity, and supervision and support. This will not only produce more robust research, but may also improve practice through clear expectations for all involved.

Finally, to summarize the available literature on coaching in education, Table 3 offers a “menu” of options that coaching interventions can consider in their design. As the research on coaching grows, many questions remain. The contributions of future research initiatives depend on clearly defining the coaching variables under study in order to document their interactions. Studies that control for specific variables to examine their unique impact are also needed.
Table 3. Summary of Coaching in the Education Literature

| Commonalities of coaching in education | supporting teacher growth  
embedded and individualized support  
systematic process that encourages teacher self-reflection |
| Terms related to coaching | coaching, mentoring, consultation, advising, technical assistance, curriculum coordination, intensive professional development |
| Terms related to coach | coach, specialist, support teacher, teacher leader |
| Who is the coach? | expert, master teacher/teacher leader, peer, self school-based, district-employed, university partner |
| Who participates? | teacher, assistant, school leader (individual or group) required, voluntary, targeted |
| Modes | onsite, remote, self |
| Roles of a coach | data coach, resources provider, mentor, curriculum specialist, instructional specialist, classroom supporter, learning facilitator, school leader, catalyst for change, learner |
| Training for a coach | initial preparation, protocols, peer support, monthly supervision, mentoring |
| Popular coaching approaches (and their key focus) | Instructional Coaching (partnership), Content-Focused Coaching, (pedagogical content knowledge), Cognitive Coaching (reflection and autonomy), Differentiated Coaching (individual teacher’s needs), and Practice-Based Coaching (teaching practices) |
| Focus | open-ended, content area, curriculum fidelity, tool to assess teaching practice |
| Possible coaching cycle components | planning meeting/pre-conference, lesson/observation, reflecting meeting/post-conference |
| Dosage | duration: average 8 months, range of 1 week to 5 years  
frequency: average 1x/month, ranges 1 time total to 3X/week  
intensity: ranges 30-90 minutes per cycle component |
| Coaching strategies | feedback, planning, monitor progress, action plan, practice new skills, modeling, relationship building, role-play |
| Related activities | workshops, coursework, professional learning communities (PLCs), book clubs, assigned readings, individual |

How Can Coaching Improve Teaching and Learning?

What is the Role of Coaching among Larger Efforts for Teacher Development?

Research has found that traditional forms of teacher professional development, such as intermittent workshops, are not sufficient to improve teaching and learning. Darling-Hammond
and colleagues (2017) reviewed 35 rigorous studies to conclude that effective professional development:

1. Is content-focused
2. Incorporates active learning
3. Supports collaboration, typically in job-embedded contexts
4. Uses models and modeling of effective practice
5. Provides coaching and expert feedback
6. Offers opportunities for feedback and reflection
7. Is of sustained duration

Notably, coaching itself is among the seven elements and was present in 30 of the 35 studies. Darling-Hammond and colleagues describe coaching as master teachers or coaches based in universities or professional development organizations that meet individual teachers’ needs either one-on-one in the classroom, by facilitating groups, or connecting remotely through technology. As detailed previously, many of the other elements of effective professional development that Darling-Hammond and colleagues identified may occur as part of coaching including content focus, active learning, collaboration, job-embedded support, modeling, feedback, reflection, and sustained duration. Prior to this report, a body of professional development research recommended similar elements (Brenneman, 2014; Desimone, 2011; Duncan, 2010; Snyder et al., 2015; Zaslow, 2014). While some claim that coaching is more expensive and time-consuming than group workshops, Brenneman (2014) cautions, “cheap [professional development] is not cheap if no benefit accrues in children’s learning.”
How Does Coaching Meet the Needs of High Quality Professional Development?

Citing the same body of research, Desimone and Pak (2017) explicitly conceptualize how coaching reflects effective professional development. They summarize the research into five features:

1. Content Focus
2. Active Learning
3. Duration
4. Coherence
5. Collaborative Participation

First, the authors explain how coaching often centers around a content focus by including lesson planning, assessment, alignment with academic standards, and attention to how students learn this content. Desimone and Pak (2017) cite research that has documented positive outcomes of subject-specific coaching in math (Killion, 2012; Neufeld & Roper, 2003) and literacy (Darling-Hammond et al., 2009; Matsumura et al., 2012). Therefore, they conclude, less content specific models may not be as impactful.

Second, the authors assert that coaching involves opportunities for active learning such as observation, feedback, discussion, and reviewing student work. In addition, research finds evidence for the power of feedback on practice (Allen et al., 2011; Biancarosa et al., 2012; Matsumara, et al., 2010).

Third, Desimone and Pak (2017) argue that coaching involves a substantial duration with multiple points of contact spread over time. They focus on dosage, citing prior research about professional development across types suggesting that teachers need 20 hours or more for it to be effective (Garet et al., 2001). Another study found teachers performed better when they had at
least 14 hours of professional development (Yoon et al., 2007). Desimone and Pak (2017) do not discuss a specific duration in terms of length of time over which coaching should occur such as days, weeks, or years, but imply that smaller dosages spread over time are more impactful than a large dosage all at once. The paper they cite from Garet et al. (2001) looked at math and science professional development in 385 school districts across one calendar year. Durations ranged from two days to over nine months. The researchers found a correlation between the “span” or period of length of interventions and the quality of the intervention in terms of coherence with what teachers already know and state standards, as well as increased opportunities for active learning. Both a longer duration and a larger dosage led to greater teacher outcomes.

Fourth, professional development efforts have demonstrated success when they exhibit coherence by aligning with curriculum and standards (Fishman et al., 2003; Stone at al., 2008) as well as when they are integrated directly into teachers’ everyday routines (Clements et al., 2011; Greenleaf et al., 2011). Coaches can align with whole school efforts, while also ensuring that the change is not top-down but rather takes a teacher’s individual beliefs and personal goals into account (Killion, 2012).

Fifth, prior research points to the positive outcomes of collective participation when teachers establish shared vision and responsibility (Desimone, 2009; Guskey, 1994), which coaching can foster. This may especially occur if coaches work in grade-level meetings or oversee study groups, argue Desimone and Pak (2017).

In their model, Desimone and Pak (2017) also address the inconsistencies in coaching in the literature and express the need for future experimental and quasi-experimental research to further understand coaching related to how, when, and why it improves teaching and learning.
How Does Coaching Impact Teaching?

To theorize how the coaching process impacts teacher development, Brown (2016) developed a conceptual framework for coaching and tested it in a coaching initiative supporting early language and literacy. The depiction of her model in Figure 2 is original to her publication. Since it obscures a portion of the text, it is described in detail below.

Figure 2. Brown’s Conceptual Framework for Coaching (2016)

Brown (2016) locates coach support at the center, embedded within the wider, ongoing continuing education efforts. These include professional development that activates the teacher’s prior knowledge, engages them in experiential learning, conveys new theory, and allows time for practical application. A teacher attempts implementation of the new information in their classroom activities, curriculum, environment, and interactions with students. Coaching occurs
through a visit characterized by planning and reflective processes, collaborations, modeling, observation, and consultation. After coaching, teachers again modify attempts at classroom implementation to address response to intervention, assessment informed instruction, and differentiation.

A noteworthy contribution of Brown’s (2016) conceptualization is the recognition that coaching does not occur in isolation from other professional development, be it formal related activities such as workshops or informal actions taken by the teacher such as reading a blog post. Furthermore, while official coaching cycles with planning, observation, and feedback may occur infrequently, coaches may offer ongoing support to teachers through e-mail or spontaneous conversations while passing in the hall. This is conveyed by locating coaching at the center of the model with arrows to suggest it is continuous. Brown’s framework also emphasizes the impact of coaching on classroom implementation by including this key aspect twice. Teachers might independently try a new teaching practice learned from professional development, meet with a coach to refine and enhance the practice, and then implement the new practice again in a way that more effectively impacts students. The difference between these two iterations of classroom implementation highlights the cyclical nature of embedded learning and suggests that classroom implementation alters between coaching visits to become more focused on students’ needs.

**How Does Coaching Impact Student Outcomes?**

Taking it one step further, Desimone (2011) explains the process by which professional development for teachers ranging from “formal, structured seminars” to “informal hallway conversations” impacts learning outcomes for students. In her words:

1. Teachers experience professional development.
2. Professional development increases teachers’ knowledge and skills, changes their attitudes or beliefs, or both.

3. Teachers use new knowledge, skills, attitudes and beliefs to improve the content of their instruction, their approach to pedagogy, or both.

4. The instructional changes that teachers introduce to the classroom boost their students learning.

While this process may appear simple, teacher change is gradual and difficult (Guskey, 2002). If a teacher attempts a newly learned teaching practice in their classroom and it goes poorly, they will likely become discouraged and less receptive to future professional development from that provider or on that topic. Through the support of a coach, however, teachers are more likely to be successful with implementation and understanding how to adapt new ideas to their unique classroom. During coaching sessions teachers are also afforded space to reflect and understand reasons behind less successful lessons, as well as offered the opinion of another set of eyes and ideas to guide next steps to improve instruction.

**How Does Coaching Impact Children and Their Families?**

More specifically, Howard and colleagues (2013) studied 384 coaches working in Head Start as part of Early Learning Mentor Coach grants. One outcome of their descriptive research was the development of a program logic model to serve as a framework for Head Start programs implementing coaching (see Figure 3).
According to their conceptualization, the ultimate goal of coaching is “positive, significant, and sustained outcomes for Head Start children and their families” which goes beyond the teacher and student outcomes typically reported in the literature. In a subsequent report, the authors explain how their model aligns well with Practice-Based Coaching (McGroder et al., 2014; NCQTL, 2008); in particular with components of identifying staff needs, observing practice, and fostering self-reflection through feedback. The model highlights: (a) the importance of the program administrator’s assumptions about why coaching is needed; (b) which staff will participate; (c) for how long; and (d) the coach’s qualifications since these assumptions will affect later decisions. With the dizzying menu of options outlined earlier in this paper, this
model may help guide centers in their decision process. The targeted options are broad, however, and do not match with the recommendations from the effective professional development literature cited above to focus on content (Darling-Hammond et al., 2017; Desimone & Pak, 2017; Kraft et al., 2018). Thus, it raises the question of how that finding applies when the goals are broader than academics, such as in Head Start, with its mission to enhance whole communities and break the cycle of poverty.

What Impacts of Coaching Have Been Documented?

The empirical research on coaching in education suggests that it positively impacts teaching practices, student achievement, teachers’ attitudes, and teacher efficacy (Kraft et al., 2018, Snyder et al., 2011; Cornett & Knight, 2009). Particularly in early childhood, coaching interventions have resulted in positive outcomes in the domains of language and literacy (Biancarosa et al., 2012; Cabell et al., 2011; Hindman & Wasik, 2012; Landry et al., 2009; Powell et al., 2010), social and emotional learning (Domitrovich et al., 2009; Raver et al., 2008), and quality of teacher and child interactions (Pianta et al., 2008). The majority of coaching studies focus on literacy (Kraft et al., 2018), and more research is needed to determine if positive outcomes translate across subject areas, suggesting the need for math-focused work.

Kraft et al. (2018) conducted a meta-analysis of 60 rigorous, causal studies of teacher coaching programs in the United States. Within the sample, 52% of studies were conducted in early childhood classrooms, 33% were conducted in elementary schools, 25% were conducted in middle schools, and 12% were conducted in high schools. Regarding coaching approaches, 67% had a content area focus (with 58% of these focused on reading) and 33% focused on general pedagogical practice. More than 90% of the coaching initiatives involved at least one other component that fell into three categories: group trainings, instructional content (such as
curriculums), or video libraries.

The researchers found pooled effect sizes of 0.49 standard deviations on instruction and 0.18 standard deviations on student achievement. While these appear close to Cohen’s (1988, 1992) medium and small effect sizes, respectively, they are large when contrasted with the greater body of literature on teacher professional development (Yoon et al., 2007) and other school-based interventions (Fryer, 2017) including “student incentives, teacher pre-service training, merit-based pay, general PD, data-driven instruction, and extended learning time” (p. 27).

**What Components of Coaching Are Necessary to Achieve These Impacts?**

Kraft and colleagues (2018) found greater effect sizes for programs that targeted specific content compared to general teaching practice, and for programs that were paired with either (a) group meetings such as workshops to build common understanding or (b) instructional resources and materials such as a curriculum. This is consistent with other studies mentioned earlier that found adding coaching to other PD approaches results in greater impact (Joyce & Showers, 2002; Neuman & Cunningham, 2009; Neuman & Wright, 2011).

Notably, Kraft and colleagues (2018) found that the effect sizes of the impact of coaching described above decreased as teacher sample size increased. Study sizes were categorized as follows: 50 participants or less (30%), 51 to 100 participants (27%), 101 to 150 participants (12%), 151 to 300 participants (8%), and 300 or more participants (2%). Thus, coaching may be less impactful when more teachers are included.

In another study, Rush and Sheldon (2011, 2005) analyzed the research on adult learning (Bransford et al., 2000; Donovan et al., 1999) and professional development in help-giving fields to determine five coaching characteristics that led to use of newly learned skills or improvement
of existing skills. These are outlined and defined below in the researchers’ words:

1. **Joint Planning** - Agreement by both the coach and the learner on the actions to be taken by the coach and/or learner or the opportunities to practice between coaching visits.

2. **Observation** - Examination of another person’s actions or practices to be used to develop new skills, strategies or ideas.

3. **Action** - Spontaneous or planned events occur within the context of a real-life situation that provides the learner with opportunities to practice, refine, or analyze new or existing skills.

4. **Reflection** - Analysis of existing strategies to determine how the strategies are consistent with evidence-based practices and may need to be implemented without change or modified to obtain the intended outcome(s).

5. **Feedback** - Information provided by the coach based on direct observation of the learning by the coach, actions reported by the learner, or information shared by the learner to explain the learner’s current level of understanding about a specific evidence-based practice.

These five components are consistent with many of the approaches described earlier, with several exceptions: (a) joint planning does not always occur as part of a coaching cycle; (b) not all coaches model teaching practices so that teachers can observe; and (c) in early childhood contexts there seems to be more directive feedback than opportunity for reflection. More research specific to early childhood education is needed to develop a deeper understanding of what occurs during each of these five components.
How Might Coaching Improve Early Math Learning?

As explored above, coaching has been shown to be an effective tool for improving teaching and learning. Preschool math is a particular area that may benefit from coaching but has been underexplored in the literature.

Why is Early Math Important?

In the United States, math education at all levels has been undergoing reform spurred by poor scores in comparison to peers in countries around the world on international tests. Traditional teaching methods involving memorized procedures are shifting to instead emphasize conceptual understanding. Most adults remember learning math by quickly completing worksheets with thirty problems on a page, but these teaching methods are now being replaced by open-ended tasks and rich discussion of just one or two problems. In other words, there is a change from a focus on children getting right answers to a focus on children understanding the process.

In early childhood classrooms, math was neglected until a growing foundation of research uncovered the importance not only for future math learning, but growth in other domains as well. For example, in an analysis of six longitudinal data sets, Duncan and colleagues (2007) found that early math competency is a better predictor of later school achievement than early reading skills, attention skills, or social emotional skills. Furthermore, math ability at age 3 or 4, especially in regard to block play, has been found to be a predictor of later math success (Wolfgang et al., 2003) as well as literacy success (Hanline et al., 2010). Advances in cognitive development research have demonstrated that human beings are born with the capacity for mathematical thinking, and that it develops along common learning trajectories (Clements et al., 2004). Positive, developmentally appropriate experiences engaging with number and operations,
geometry, algebraic reasoning, and measurement under the guidance of a knowledgeable teacher can “help children to develop dispositions such as curiosity, imagination, flexibility, inventiveness, and persistence, which contribute to their future success in and out of school” (NCTM, 2013, p. 1).

As a result, early math education research and professional development initiatives continue to gain momentum. A prior review of the published literature on math education for children birth through age eight found 208 articles published between 2000 and 2005 (Fox & Deizmann, 2007), whereas a review conducted in 2017 found 1141 articles published between 2005 and 2015 (Linder & Simpson, 2017). In addition to increasing research, policy is shifting as well. The recently reauthorized Every Student Succeeds Act (2015) includes cognitive and mathematics domains for young children, and the adoption of the Common Core State Standards for K-12 (CCSS, 2017) by 42 states has teachers from all grades working to reform their practice.

While the new CCSS do not directly include preschool, they create pressure to change approaches to math teaching and learning in early childhood settings. Many early childhood education programs recognize a need to provide a strong foundation so children are prepared for kindergarten. All 50 states include math in their early learning standards, and many have begun to align with CCSS (Spaepen, 2017). If teachers do not understand developmental progressions and how to appropriately assess emerging mathematical understanding, however, inappropriate pushdown of skills more appropriate for older children may occur. Therefore, teachers working with children age three to six need expertise in mathematical content and effective teaching practices that consider children’s developmental stages.
What Do We Know About the Potential of Coaching Around Math from Upper Grades?

As previously noted, published studies about math coaching are rare even in upper grades. In a research brief, McGatha (2009) found seven studies that demonstrate coaching impacts on teachers’ practice in elementary in middle school settings. Outcomes include: (a) teachers emphasizing interconnected concepts rather than isolated topics; (b) teachers promoting problem-solving over skill-based instruction; (c) teachers using student work to inform instruction, and (d) increases in the amount of student discussion (Becker, 2001; McGatha 2009). As noted previously, a study of third, fourth, and fifth grade teachers found greater student achievement after three years in classrooms of teachers who worked with expert coaches (Campbell & Malkus, 2011). In middle school, a case study revealed evidence of increased student achievement in the classrooms of teachers who received math coaching (Obara & Sloan, 2009). These studies are limited as they rely on qualitative findings with small sample sizes.

What are the Challenges and Needs Specific to Early Childhood Education Regarding Math?

In early childhood and elementary teacher preparation programs, math coursework and field experiences are limited (Copple, 2004; Fennell, 2011; Ginsburg et al., 2006; Institute of Medicine, 2015). Across a series of studies, findings indicate early childhood teachers believe social and emotional development, physical well-being, and literacy are more important than math (Hyson & Woods, 2014). Some educators think they are teaching math through their daily calendar routine, not realizing the context is more about social studies and does little to promote mathematical understanding (Beneke et al., 2008). A child’s ability to recite the number sequence from memory is often misinterpreted as understanding of number, and identifying shapes by their names takes precedence over understanding their attributes. Overall, early
childhood teachers have lower levels of math content knowledge and more traditional beliefs compared to teachers from older grades (Linder & Simpson, 2017). They also report higher levels of mathematical anxiety (Copley, 2014; Gresham, 2007) and negative math experiences in their own schooling background (Drake et al, 2001).

A challenge in educating teachers is the fact that all teachers were once students themselves. Teachers carry beliefs--and misconceptions--about teaching from the way they were taught, making reform in any subject a challenge (Darling-Hammond & Bransford, 2005). This becomes especially apparent in math, where teachers are now asked to use methods different from those they experienced as students. Further, early childhood teachers must acquire not only new pedagogies, but new mathematical content knowledge to fill gaps in their own schooling since research indicates the single most determining factor of what children learn is what their teachers know (Darling-Hammond & Bransford, 2005). Since teaching is so personal, dispositions including beliefs, attitudes, and confidence therefore play an important role in the change process.

Beyond math, the early childhood workforce faces challenges such as high teacher turnover and financial limitations (Institute of Medicine, 2015; Zaslow, 2009). The many teachers working with children, including certified lead teachers, teacher assistants, aids, and paraprofessionals, have great variability in their backgrounds with a range of credentials from a high school diploma, to a two-year associates degree, to a four-year bachelor’s degree or more (Brenneman, 2014). Learning contexts are also diverse with locations including Head Start centers, Pk-8 schools, stand-alone preschool sites, private childcare centers, and family childcare homes.
What is the Potential of Coaching to Improve Early Math?

In order to improve math learning for young children, early childhood teachers need support to improve their skills in math teaching. A large body of research demonstrates that workshops alone are not effective (Darling-Hammond et al., 2017). In a study of preschool teachers that found no changes in teachers’ presentation of math learning opportunities or children’s math learning outcomes the authors concluded that, “provision of high-quality professional development does not ensure that content becomes integrated into classrooms practices” and note the need for “systematic means of ensuring that educators [have] regular opportunities to apply new content to their classrooms” (Piasta et al., 2015).

Since coaching is tailored to teachers’ unique context and needs, it has the potential to meet teachers where they are and build upon their strengths in order to equalize the disparities in teacher preparation. The embedded nature of coaching can also allow initiatives to adapt to the diverse settings in which early childhood teachers work. A reflective environment may help teachers overcome math anxiety, and a systematic coaching approach may support incremental change.

What Has Research on Early Math and Coaching Found?

Literature specific to coaching around math in preschool is extremely limited. Of 49 studies about coaching with teachers serving children ages 0 to 5 reviewed in 2015 by Artman-Meeker and colleagues, only one focused on math. Rudd and colleagues (2009) discovered an increase in toddler teachers’ use of “math mediated language” after four sessions of side-by-side coaching compared to teachers who only attended a two-hour workshop.

More recently, Germeroth and Sarama (2017) reported on coaching in two studies conducted as part of preschool math professional development. The first study, TRIAD, focused
on implementation of the Building Blocks math curriculum, and included two types of coaches in addition to “PD sessions.” “Peer coaches” were teachers involved in the project who served as leaders within their schools, and “mentors” were experts either from within the schools or the project staff. Mentors visited at least once per month and played six main roles: observation, intervention support, fidelity check, administrative, curriculum consultation, and resource provider. Children whose teachers were assigned mentors and peer coaches learned more math than those in the control group, although the authors caution that cause cannot be attributed to coaching alone.

The second study, EMEGE, combined the Building Blocks math curriculum with the Tools of the Mind social-emotional curriculum. Coaching was similar, except all mentors were from the district. Interestingly, mentor attendance was poor at PD sessions with only 9% attending all eight. The authors note the importance of training and supporting coaches not just in the content of coaching but also the process. Student results were not statistically significant, leading the authors to conclude that, “implementing multiple interventions simultaneously may limit desired outcomes” (p. 159). They are conducting further analysis to understand the role of less satisfactory coaching.

In a publication on a larger professional development initiative, Chen and McCray (2012) report “on-site coaching” as one of three critical components that led to student learning gains of three to five months for Head Start, preschool, and kindergarten children in Chicago Public Schools. Workshops called “Learning Labs” and classroom implementation of common “research lessons” were the other two components. Coaches are described as veteran teachers trained by project staff following an adaptation of the Cognitive Coaching model with planning, observation, and analysis. The coaching dosage consisted of three cycles per year for an intensity
of about one hour each. A notable finding was the importance of having teachers implement common lessons, directly related to Learning Lab content, which the coaches could study together in depth to be better prepared when meeting with teachers.

Overall, research on multiple effective math interventions in early childhood has found coaching and mentoring to be a critical component alongside intensive workshops and school-wide support in effective math interventions (Brenneman, 2014; Clements & Sarama, 2012; Copley, 2014; Institute of Medicine, 2015; Germeroth & Sarama, 2017). Other contributing factors include a research-based framework, an emphasis on developmental progressions and learning trajectories (Ginsburg et al., 2014), and attention to knowledge, practice, and attitudes (Chen & McCray, 2012). While coaching is mentioned among these findings, it is rarely described in great detail nor studied specifically. Further research may help disentangle the contributions of coaching from other activities and allow stakeholders to better understand the role it plays in improving early math teaching and learning in varying contexts.

What are the Opportunities for Future Research on Coaching Teachers around Early Math?

The lack of research that details coaching around this particular topic points to opportunities for future studies to be explicit in their reporting about coaching as a method to improve math teaching and learning in early childhood contexts. The education field as a whole can benefit from publications in which researchers articulate coaching decisions regarding the variables outlined in this review. Defining coaching will allow scholars to be sure they are discussing the same set of activities rather than convoluting concepts. Once the variables are clear, researchers can systematically vary them to determine how they interact and ascertain the affordances and challenges of specific coaching approaches with specific educators in specific
contexts. Studies that look at the long-term impacts of coaching are also needed to contribute information regarding sustainability.

Of particular interest are coaching approaches that involve education professionals other than lead teachers such as assistants, aids, and paraprofessionals. This is especially vital in early childhood settings where multiple teachers work together in the same classroom. Similarly, research on group coaching has mixed findings and requires further examination. Evidence points to the importance of involving leaders in professional development initiatives but understanding of their role in coaching is lacking.

Furthermore, future research efforts will contribute to the field by including information regarding the credentials of the coaches involved in their studies and how they were trained and supported. Since math has a history of being neglected in early childhood settings, finding individuals who understand both young children and the content area may be a challenge. What might be the role of a coach’s content knowledge in effective coaching? How might a coach’s understanding of learning trajectories in math impact student outcomes? In a school-based coaching setting, for example, a teacher who left a third-grade classroom to become a coach may not understand developmental expectations when coaching a preschool colleague.

Additionally, research in early childhood math professional development has considered the importance of shifting teachers’ dispositions in order to shift their practice (Ginsburg et al., 2014). What role might coaching play in this process? Theories posit that the reflective nature of coaching allows for more teacher involvement in their own change process rather than a “top down” approach. How do early childhood teachers of math experience their coaching relationship? Does it differ among lead teachers, assistant teachers, and leaders?
Conclusion

In conclusion, coaching is a complex process that holds potential for improving early math teaching and learning that requires further research with explicitly defined variables. Increasing recommendations and requirements for coaching in early childhood settings, combined with increased awareness of the importance of early childhood math, make the topic especially relevant. Coaches, teachers, policymakers, school administrators, and other stakeholders can benefit from future research contributions on early math coaching to guide their work and ultimately improve educational opportunities for the children in their care. The following sections detail the Theoretical Framework and Research Questions guiding the present study.

Theoretical Framework for the Current Study

The theoretical perspective for the current study is informed by the Whole Teacher Approach (Chen & McCray, 2013), which defines teacher outcomes in terms of knowledge, practice, and dispositions. It is also informed by the logic model designed for Collaborative Math in Head Start (McCray et al., 2015), which situates coaching within the larger context of a professional development initiative. Finally, the theories related to coaching in Head Start set forth in the Logic Model in Head Start (Howard et al., 2013) help hypothesize the specific role of math-focused coaching specific to this context. Each of these three influences on the theoretical framework for the current study is described in detail below.

The Whole Teacher Approach

Inspired by approaches that honor the “whole child” the Whole Teacher Approach (WTA) applies this concept to adult learners as it concentrates simultaneously on the cognitive, behavioral, and social/emotional aspects of teachers’ growth (see Figure 4). Under the WTA
framework, teacher professional development addresses teachers’ knowledge by conceptually structuring intervention content around key topics children need to understand known as “big ideas,” as well as research-based learning trajectories outlining how children’s thinking and understanding typically develop. Teachers apply this knowledge and improve practice by trying common “research lessons” in their classroom and working with colleagues to analyze which teaching strategies best bring out “big ideas” for children. Finally, teachers’ attitudes and beliefs about math are targeted through adult learning activities that engage teachers in fun mathematical challenges coupled with dedicated time for reflection and collaboration.

![Diagram of the Whole Teacher Approach to Teacher Professional Development](image)

Figure 4. The Whole Teacher Approach to Teacher Professional Development (Chen & McCray, 2013)

The WTA differs from other theoretical frameworks for teacher professional development and coaching which typically concentrate on practice alone. The inclusion of dispositions makes it especially well-suited for interventions that aim to improve teaching and learning in the area of early math, since as previously noted early childhood teachers report more traditional beliefs than elementary teachers (Linder & Simpson, 2017), higher levels of mathematical anxiety (Coley, 2014; Gresham, 2007), and often negative math experiences in
their own schooling experiences (Drake et al., 2001). The whole teacher approach has been applied broadly across elements of professional development interventions, but not to coaching specifically.

**Collaborative Math Logic Model**

Using the WTA approach and expanding upon the prior work of Chen and McCray (2012), Collaborative Math in Head Start is an impact study led by Erikson Institute’s Early Math Collaborative and SRI International with funding provided by the National Science Foundation. Research is currently underway in 27 Head Start centers in partnership with a local Head Start grantee agency. The four-year study is designed to test the extent to which a new professional development model focused on all teachers and leaders working with children ages 3-5 can help Head Start “establish centers of excellence in mathematics where quality early math instruction is fostered, celebrated, and sustained.” It also gathers evidence of its promise for improving mathematical competencies of Head Start staff, as well as the math learning of the children they serve.

Collaborative Math is guided by *The Big Ideas of Early Math* book (Brownell, 2014) but not associated with any particular curriculum. Collaborative Math aims to help teachers find their own “math lens,” allowing them to make their instruction responsive to the varying developmental levels and diverse cognitive, cultural, and language needs of the Head Start population. The intervention focuses on math content organized into “big ideas” with corresponding common “research lessons” and “family engagement.” For example, participants attend a Learning Lab about the topic “sets and sorting” with focus on two “big ideas:” (a) “Attributes can be used to sort collections into sets;” and (b) “The same collection can be sorted in different ways.” Participants also explore a research lesson called “Sorting Stations” in which
children explore and apply these “big ideas” under the guidance of their teacher. Participants are encouraged to engage parents with recommendations including (a) asking families to contribute materials for the stations such as buttons, bread tags, bottle caps and other “treasures” from home; (b) sending a letter home about ways they may already sort such as laundry and dishes; and (c) documenting how the students sort at school using photographs and displaying it for families to view. Other focus topics include number sense, subtizing (the ability to quickly perceive a small quantity 1-4 without enumerating), principles of our counting system, and shape. The 8-month long intervention consists of four main intervention inputs:

1. Six 3-hour Learning Labs designed to increase educators’ understanding of math content and effective teaching practices which are attended by classroom “teachers” (anyone working directly with children, including leads, assistants, and aids) and “instructional leaders” (including directors and education coordinators)

2. Seven 3.5-hour Leadership Academies attended by instructional leaders to increase content knowledge and assist leaders to support their staff

3. Monthly 1-hour Consultations between coaches and instructional leaders to support center-wide components and logistics

4. Group Coaching with coaches, teachers, and occasionally instructional leaders which is described in detail below.

To support adult learning, facilitators speak both English and Spanish, and handouts for teachers are available in both languages. Additionally, bilingual coaches are assigned to support centers that serve Spanish-speaking families.

These four inputs are hypothesized to transform the Head Start partner sites into “functioning Collaborative Math Centers of Excellence” where strong math teaching and
learning is sustained, which in turn will result in “Kindergarten Math Readiness.” This process is supported through developing the math content, practice, and dispositions of leaders and teachers who can then create collaborative change across classrooms and across centers. The logic model in Figure 5 created by the Collaborative Math in Head Start Study’s Co-Principal Investigators Jennifer McCray, Erin Reid, Ximena Dominguez, and Erika Gaylor (2015), provides a full overview.

Figure 5. Collaborative Math in Head Start Logic Model (McCray et al., 2015)

The current study will zoom in on Group Coaching. During Group Coaching, teaching teams who work together in the same classroom meet on-site with a coach employed by Collaborative Math. A total of five coaching cycles take place about monthly from November to April in between Learning Labs. Coaching is an expectation for all participants in the intervention, including lead and assistant teachers, rather than optional or targeted for those most in need. In addition to visiting participating sites, coaches also co-facilitate Learning Labs each cycle alongside senior project staff. To conceptualize what may occur during the coaching
process, prior work specific to Head Start from Howard and colleagues (2013) acts as a starting point.

**The Program Logic Model for Coaching in Head Start**

As explained in the review of the literature, Howard and colleagues (2013) studied 384 coaches working in Head Start as part of Early Learning Mentor Coach grants to develop a program logic model for coaching specific to Head Start (see Figure 6). Intended to help Head Start program leaders plan for coaching, it provides a useful structure to conceptualize the coaching process and components, while also theorizing the impact beyond teachers to children and families.

![Program Logic Model for Coaching in Head Start](image)

**Figure 6. Program Logic Model for Coaching in Head Start (Howard et al., 2013)**
In this model, the ultimate goal is “positive, significant, sustained outcomes for children and families.” It suggests programs must first consider assumptions about why coaching is needed, which staff need or could benefit from coaching, the key qualifications for coaches, and how long it will take to change practice. The answers to these assumptions influence the coaching approach, which also depends upon available inputs, including internal and external supports such as a buy-in and training, plus resources including space, technology, and materials. Outputs include dosage, staff-coach relationships, and staff engagement, and the targeted outcomes include improved staff knowledge and practice, improved quality of classrooms, and staff professional development. These are further conceptualized to lead to child and family outcomes. This process takes place in the context of the Head Start program and its surrounding community. Unlike the logic model for Collaborative Math, this model developed by Howard and colleagues’ is not content-specific and locates the control of the intervention within the program itself rather than in a partnership with an outside organization. Therefore, a new model combining these two along with the Whole Teacher Approach is necessary for the current study.

**Logic Model for the Current Study**

Combining the frameworks described above, the logic model for the current study (see Figure 7) hypothesizes how an outside organization collaborating with Head Start centers can use coaching to directly impact teachers and teaching. Important indirect child and family impacts are also included, but shaded since they are beyond the scope of the current study. Information for this hypothesized model was gathered from the researcher’s personal experience working as a coach for the project. Study findings will allow for further refinement and understanding of the model by incorporating the perspectives of project development staff, coaches, and teachers.
The Collaborative Math intervention assumes that all teachers in classrooms serving children ages 3-5 can benefit from coaching and therefore does not target select individuals at a site. The goal of coaching is to improve teaching quality by honoring the whole teacher, and prior research has found that teacher quality impacts student outcomes. Inputs are conceptualized within a partnership. Head Start centers provide time for teachers and coaches to meet, and directors provide support through logistics arrangements such as time for meetings plus insight into what has occurred in classrooms in between coach visits. The partner organization, Erikson Institute’s Early Math Collaborative, provides (a) content during Learning Labs; (b) research lessons for teachers to practice implementing new ideas with children; (c) structures and forms to organize this process; as well as (d) intentionally pairing Spanish-speaking coaches with Spanish-speaking sites. Experienced coaches who are math content experts are hired and
supported by the partner to work directly in the centers, therefore acting as a bridge between both.

The coaching approach focuses on math content. Planning and reflecting meetings occur in group settings with all lead and assistant teachers who work together in the same classroom at the same time. During the lesson, each teacher takes a turn leading as a coach observes, moving in tactfully to ask a question or co-teach when necessary. This may be a shift from their normal classroom routines in which only the lead teacher is in charge of lessons and the assistant offers support. The philosophy is that all adults in the classroom are teachers interacting with children throughout the day and everyone’s math content knowledge, practice, and dispositions must be improved to benefit students. While in classrooms, coaches focus on teachers and do not work directly with children. During reflecting meetings, coaches also spend time strategizing how to engage family with math activities, assisting teachers to implement a classroom math lending library (with books provided by the partner), and helping teachers mathematizing daily routines such as attendance and transitions.

The outputs of this approach include a dosage of five monthly cycles between November and April of the same year, and a targeted total of about 700 minutes (five 1-hour planning meetings, five 20-minute lessons, and five 1-hour reflecting meetings). Similar to the model by Howard and colleagues, a relationship between teachers and coaches, as well as teachers’ engagement in their own professional development, are additional outputs. Direct outcomes include the development of the whole teacher in regard to math, which differs from other studies that conceptualize coaching to focus only on practice (Kraft et al., 2018). Indirect outcomes are growth in children’s math skills, as well as family support of this development. This process all
occurs in the context of the relationship between the partner organization and the Head Start program. The current study offers an opportunity to test this logic model.

**Research Questions**

As Head Start programs begin to meet coaching requirements mandated by the recent updates to the *Head Start Performance Standards*, the knowledge gained from this study can help guide their choices while highlighting the need for early math education. It can also inform thinking about coaching frameworks, dosage, cycle components, and strategies for intervention programs that partner with Head Start to support and provide coaching, as well as offering insight to other early childhood contexts. The current study seeks to answer the following research questions. Each is then hypothesized and explained below.

**Main Research Question**

How does math-focused coaching impact preschool teachers’ content knowledge, teaching practice, and dispositions (attitudes, beliefs, and confidence)?

**Research Question 1**

What is Collaborative Math’s coaching model?

a. Which components are most salient to the coaching process as reported by coaches, teachers, and project materials?

b. What are the qualifications and demographics of Collaborative Math coaches?

**Research Question 2**

What is the unique contribution of coaching among other intervention inputs?

a. After accounting for pretest scores, Learning Lab attendance, instructional leader support, and teacher demographics, do varying amounts of coaching predict shifts in knowledge, practice, and/or dispositions?
b. How do coaches and teachers describe shifts in knowledge, practice, and/or dispositions in relation to coaching? What other coaching-related outcomes do they mention?

*Research Question 3*

What factors facilitate and inhibit the outcomes of the coaching process? What possible factors do coaches and teachers suggest?

**Hypothesis**

**Hypothesis for Research Question 1**

The logic model in Figure 7 hypothesizes Collaborative Math’s coaching model based upon the researcher’s personal experience. Research Question1 will add perspectives from teachers, coaches, and official documents. Collaborative Math’s coaching model was originally influenced by *Cognitive Coaching* and developed organically in response to field experience and ideas from other coaching models. While there are coaching forms, protocols, and overviews, the model has yet to be comprehensively defined. The coaching model appears similar to Practice-Based Coaching (Artman-Meeker et al., 2015; NCQTL, 2008; Snyder et al., 2015) with a focus on early childhood, an emphasis on collaboration, and a three-phase cycle including planning, observation, and reflection. The major difference seems to be a focus on math, which makes Collaborative Math’s model appear similar to Content-Focused Coaching (West & Cameron, 2013; West & Staub, 2003). Content-Focused Coaching, in contrast, is intended for school-based coaches working with older children and is not tailored to Head Start settings. Collaborative Math’s model is different from those in the reviewed literature in that (a) the coaching occurs in a group setting rather than individually, and (b) instructional leaders are present for some sessions. It is hypothesized that these two factors are key aspects of the coaching model.
Hypothesis for Research Question 2

It is hypothesized that participation in coaching will lead to significant shifts in teachers’ knowledge, practice, and dispositions as demonstrated by quantitative analysis of teacher outcome measures. Prior research finds that interventions involving coaching lead to positive outcomes in teacher’s knowledge and practice (Kraft et al., 2018). It may be possible that coaching impacts practice most since this is its main focus. Since coaches facilitate Learning Labs and focus each coaching cycle around a particular mathematical “big idea,” coaching likely impacts content knowledge as well. As coaches grow relationships with teachers and assist them to improve math teaching their dispositions may similarly shift. It is also likely that higher dosages of coaching lead to greater teacher outcomes by affording more time and attention for shifts to occur. Qualitative analysis will deepen understanding of the change process by which they occur by remaining open to emerging factors.

Hypothesis for Research Question 3

The researcher hypothesized that the amount of time spent in coaching meetings will positively correlate with increased shifts in teachers’ knowledge, practice, and dispositions as demonstrated by quantitative analysis. Prior studies find mixed results regarding the impact of dosage. For professional development in general, including workshops, study groups, professional learning communities, and coaching, Yoon and colleagues (2007) found 14 hours were necessary to obtain a significant impact, whereas Garet and colleagues (2001) suggest 20 hours or more are needed. In their meta-analysis of professional development interventions involving coaching, Kraft and colleagues (2018) calculated both the total number of hours spent in one-on-one coaching, as well as the total number of all professional development activities including coaching and workshops. They did not find evidence that either must be high-dosage
to be effective, although with reservations about reliability due to insufficient reporting on dosage defined as hours teachers spent one-on-one with their coach. Many studies do not report this at all, or convolute it with the hours coaches spend observing and/or hours teachers spend in workshops. In one particular example, Germeroth and Sarama (2017) found it difficult to connect coaching hours to child outcomes because coaches were asked to spend more time with teachers demonstrating greater need, concluding, “it may have been better, at least for our research purposes, to have fixed schedules for coaching” (p. 146). Collaborative Math avoids this issue through a design that intends for all lead and assistant teachers to participate equally for a total of five planning conversations, five lesson observations, and five reflecting conversations. The time each teacher spends with a coach is expected to be about one hour per conversation and 30-minutes per observation, totaling 2.5 hours per cycle. This results in a total of approximately 12.5 coaching contact hours for each teacher. Low dosage may be due to teacher absence or scheduling conflicts, and coach logs will provide insight on issues that future programs can strategize to avoid. A possible contribution may be deeper understanding of obstacles that prevent teachers from obtaining the planned dosage. It is also possible that the quality, rather than the quantity, of coaching sessions matter and coaching logs and fidelity surveys can provide insight if dosage does not moderate outcomes.
CHAPTER THREE

METHODOLOGY

A mixed methods design (Creamer, 2018; Creswell & Plano Clark, 2011) was chosen in order to expand upon existing quantitative data from Collaborative Math: Creating Sustainable Excellence in Mathematics for Head Start (Collaborative Math in Head Start Study) to answer unexplored questions about the contributions of coaching within the intervention. Led by Co-Principal Investigators Jennifer McCray and Erin Reid of Erikson Institute, and Ximena Dominguez and Erika Gaylor of SRI Education, this project examined the impact of Collaborative Math, a center-based, professional development program for early childhood teachers about math that combines traditional workshop learning experiences with on-site group coaching. The current study used data collected during the Collaborative Math in Head Start Study to answer new questions specific to coaching that went beyond the original research design, as well as conducted new surveys and collected additional documents for content analysis.

Combining qualitative and quantitative methods strengthens findings while fulfilling a need in the literature for rich descriptions of coaching in early childhood settings, especially in relation to math. The qualitative data also promote the inclusion of teachers’ and coaches’ voices, which are underrepresented in education research literature. Using mixed methods allows for both the analysis of contextualized data and generalizable data at the same time (Hay, 2016). Seeking to understand the problem “holistically” can bridge methodological divides and promote
cross discipline efforts to understand and improve social issues (Weisner, 2016). In addition, combining both types of research approaches allows greater validity through triangulation of findings across sources, while also offsetting the weaknesses inherent to either design (Bryman, 2006).

The relevant design features and measures of the larger study are described below first to provide context and are then followed by the participants, new qualitative measures, and data analysis plan of the present study.

**Collaborative Math in Head Start Study Design**

Researchers utilized a cluster-randomized controlled trial to evaluate the impact of the Collaborative Math intervention in shifting teachers’ dispositions, knowledge, and practice.

**Recruitment**

Through a partnership with a local Head Start grantee, centers with 2-5 classrooms serving children ages 3-5 were invited to apply to for Collaborative Math’s professional development intervention. Research staff (including the author of the current study) presented to directors at meetings, sent emails, and made phone calls. After centers applied, researchers visited sites to meet with teachers to explain the project and anonymously survey them about their interest in participating. The survey results were not shared with directors, and used to determine if the intervention was perceived as a good fit by the staff in addition to the leader’s desire to be involved. A total of 28 centers that met criteria and demonstrated an ability to commit to participation in Collaborative Math were accepted. This included 85 classrooms with approximately 1,275 children enrolled in full day programs.

Centers were grouped by delegate agency and number of classrooms (2-3 versus 4-5), and then randomly assigned to intervention and comparison conditions for the 2016-2017 school
year. Centers assigned to the comparison group received the intervention the following year. In the treatment condition, a total of 87 staff at 14 centers working in 41 classrooms with about 615 children participated in the Collaborative Math intervention. During the same year, 105 staff at the 14 centers in 44 classrooms working with about 660 children in the control condition were offered the option to participate in a 3-hour literacy workshop and otherwise continued “business-as-usual.”

**Consent**

The Collaborative Math in Head Start Study’s staff visited each center to explain the research and obtain signed consent forms, available in both English and Spanish, from interested teachers and instructional leaders. Participation in the Collaborative Math in Head Start Study’s research was voluntary and did not impact participation in Collaborative Math intervention activities. All decisions are confidential and participants were allowed to discontinue research activities at any time. See Appendix B for a copy of the teacher consent form in English.

**Participants**

A total of 179 teachers consented to research activities. Teacher demographic information including gender, race/ethnicity, and education is presented in Table 4 broken down by intervention and comparison conditions. The majority of participants identify as female and Black/African American and/or Hispanic/Latinx. White/Caucasian was the next most frequently selected identity. Almost all participants have some college, with the largest percentage obtaining bachelors’ degrees, followed by associate degrees and then graduate degrees.
Table 4. Teacher Demographics for Collaborative Math in Head Start Research Study

<table>
<thead>
<tr>
<th></th>
<th>Intervention (n = 87)</th>
<th>Comparison (n = 92)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>73%</td>
<td>86%</td>
</tr>
<tr>
<td>Male</td>
<td>2%</td>
<td>8%</td>
</tr>
<tr>
<td>Prefer not to answer</td>
<td>1%</td>
<td>2%</td>
</tr>
<tr>
<td>Race/Ethnicity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>American Indian / Alaskan Native</td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td>Asian / Pacific Islander</td>
<td>1%</td>
<td>4%</td>
</tr>
<tr>
<td>Black / African American</td>
<td>35%</td>
<td>35%</td>
</tr>
<tr>
<td>Hispanic / Latinx</td>
<td>33%</td>
<td>35%</td>
</tr>
<tr>
<td>White / Caucasian</td>
<td>14%</td>
<td>21%</td>
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<tr>
<td>Other</td>
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<td>2%</td>
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<tr>
<td>Prefer not to answer</td>
<td>2%</td>
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<tr>
<td>Missing</td>
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<td>13%</td>
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<tr>
<td>Education</td>
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</tr>
<tr>
<td>High School degree or equivalent</td>
<td>2%</td>
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</tr>
<tr>
<td>Some college but no degree</td>
<td>8%</td>
<td>12%</td>
</tr>
<tr>
<td>Associate degree</td>
<td>20%</td>
<td>24%</td>
</tr>
<tr>
<td>Bachelor degree</td>
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<td>48%</td>
</tr>
<tr>
<td>Graduate degree</td>
<td>20%</td>
<td>9%</td>
</tr>
<tr>
<td>Missing</td>
<td>12%</td>
<td>8%</td>
</tr>
</tbody>
</table>

Procedures

A team of trained videographers visited centers to record video data of teaching at two time points: in September 2016 before the intervention began and in May 2017 as it concluded. At each time point, three different videos from three different days were captured for each teacher. Teachers were asked to interact with children around math during the visits and could choose any activity and topic. These data will be used to assess teaching practice using a tool called EQUIP-M that will be described in the measures section. In addition, researchers e-mailed teachers online surveys created using Survey Monkey in fall and spring. These surveys included PM-PCK, a measure about content knowledge, and ABC-PM, a measure to capture attitudes, beliefs, and confidence. Teachers received stipends totaling up to $150 for completing each
research activity. All participants were assigned code numbers to protect their identities. Data are stored in a password protected online database, and videos are stored on a password-protected drive in a locked office.

Measures

At this time, reliable and valid instruments to measure teacher change in relation to early childhood math are not widely available. Using the Whole Teacher Approach framework, the Erikson Early Math Collaborative research team is developing three measures to capture shifts in (a) dispositions, (b) pedagogical content knowledge, and (c) teaching practice. In addition, coaches completed logs and fidelity surveys after each group coaching conversation. Furthermore, teachers took two surveys at the conclusion of the intervention regarding their experience participating in Collaborative Math along with their demographic information. Each of these seven tools is described in detail below.

*Attitudes, Beliefs, and Confidence in Preschool Mathematics (ABC-PM)*

This online survey asks respondents to rate their agreement (1 = Strongly Disagree; 5 = Strongly Agree) with statements related to their dispositions about early math teaching and learning. Specifically, it measures (a) teachers’ *attitudes* toward math in general and their enjoyment in teaching math; (b) teachers’ *beliefs* about the appropriateness of early math for young children; and (c) teachers’ *confidence* in understanding math content for teaching and engaging children with this content through pedagogical approaches. ABC-PM is based upon a prior tool for elementary teachers, ABC-EM, with questions adapted to be appropriate for preschool teachers. After the pilot study, Collaborative Math researchers used exploratory factor analysis to decide that the tool was not effective at capturing preschool teachers’ *beliefs* about math (Quest et al., 2016) so questions regarding this aspect were omitted from the final survey
administered to participants. Thus, only attitudes and confidence were measured. (See Appendix C for a copy of the final survey that was administered to participants with 28 questions.) Also note that the present study was designed assuming beliefs were still included and thus the construct is referenced throughout and included in qualitative analysis.

**Pedagogical Content Knowledge in Preschool Mathematics (PM-PCK)**

This online survey assesses pedagogical content knowledge specific to math. Respondents read two short scenarios about children playing in a preschool classroom, and are asked to identify examples of “math” in the play. “Hits” on important mathematical ideas receive points. This measure has previously been used in the U.S. in an interview format (McCray & Chen, 2012), which found evidence of construct validity through child and teacher outcomes: one interview point per 7.75 instances of math-related talk during circle time and one interview point predicting 2.3 points of gain on the Test of Early Mathematics Ability, an assessment for preschool children (TEMA-3; Ginsburg & Baroody, 2003). In addition, PM-PCK has been successfully adapted to a survey format in Germany (Anders & Rossbach, 2015), and has recently been piloted in a survey format in the U.S. with promising results. (See Appendix D for a copy of this instrument.)

**Evaluating Quality Interactions in Preschool Math (EQUIP-M)**

This teacher observation tool measures the quality of interactions during an episode when a teacher plans to interact with children around math. Teachers select lessons of their choice and are videotaped on three separate visits during each time point. Videos are then randomized and trained coders score each video on three dimensions: (a) teacher intentionality, (b) teacher responsiveness, and (c) student mathematical sense-making. Each dimension has 3 indicators that can each receive a score of 0-3. The tool was developed and refined over the course of two
years by a team of six early math experts including researchers, coaches, and former teachers. Inter-rater reliability from a recent development trial found average intraclass corrections (ICCs) ranging from fair (.50) to excellent (.84). (See Appendix E for an overview of this tool.)

**Group Coaching Log**

Coaches use this log as both a protocol to guide the questions they ask teachers during meetings, and as a space to document teacher responses. Questions during Planning Conversations target (a) the math content of the lesson and links to the teachers’ existing curriculum; (b) anticipated student responses; (c) teacher actions and language to support learning; and (d) logistics such as materials and location. Questions during the Reflecting Conversations ask (a) how well the lesson went in relation to the math content; (b) which interactions the teachers identified as allowing them to help children think about the math; (c) what changes teachers might make next time; (d) how co-teachers will support each other; and (e) how teachers will inform and engage families in the math content. Coaches complete the log during and after each meeting with the classroom teaching team. They use these forms for their own planning purposes, and submit a copy to Collaborative Math project staff for accountability. The completed logs are not intended to be shared with teachers or instructional leaders.

Approximately 425 logs were created during the 2016-2017 intervention year (five cycles with teaching teams from 85 classrooms). (See Appendix F for this form.)

**Instructional Leader Consultation around Group Coaching Log**

Coaches use this log to document discussions between coaches and instructional leaders that occurred in meetings before and after group coaching conversations with teachers.

Instructional leaders are asked to shadow at least one classroom per coaching cycle for the full planning, lesson, and reflecting. The purpose of these meetings is to help prepare instructional
leaders to take over coaching at the conclusion of the intervention in order to continue improving math instruction at the site. Questions ask about how best to support the teachers, and allow the leader to reflect on coaching strategies they might integrate into their own practice. Coaches complete this log during and after consultations, and submit a copy to Collaborative Math project staff for accountability. The completed logs are not intended to be shared with instructional leaders. Approximately 70 logs were created during the 2016-2017 intervention year (5 cycles at 14 centers). (See Appendix G for this form.)

*Coaching Fidelity Survey*

The purpose of this survey is to document coaching conversations. Coaches record meeting length and teacher attendance, among other variables. There is also space for open-ended responses to capture any additional information. Results of the survey are not shared with the classroom teachers or Head Start directors. Approximately 425 fidelity surveys were created during the 2016-2017 intervention year (five cycles with teaching teams from 85 classrooms). (See Appendix H for a copy of this form.)

*Successes and Challenges Survey – Teachers (Teacher Survey)*

The purpose of this survey is to collect participant feedback on their experience with Collaborative Math. It is administered online at the conclusion of the intervention and consists of 25 open response questions asking about learning labs, group coaching, classroom math activities and routines, documentation boards, family math activities, and the math lending library. Teachers’ responses to questions 4-9 about group coaching were examined for the current study. Teachers were asked about (a) their relationship with their coach; (b) how coaching influenced their teaching team’s math teaching, including skills and knowledge gained from coaching; (c) the benefits and limitations of being coached with colleagues; (d) how
teachers describe their role and their coaches role in planning for and reflecting on math activities; (e) the benefits and limitations of having the instructional leader attend coach meetings; and (f) what suggestions for improvement they would offer to coaches. In order to further isolate the impact of coaching, questions 1-3 about Learning Labs were also examined as a contrast. Teachers were asked about (a) which Learning Lab experience had the greatest impact on their day-to-day work in the classroom; (b) the biggest challenges in applying what they learned about in labs to their work in the classroom and what could help overcome them; and (c) the most important ideas that preschoolers need to understand about number sense, and (d) how they would have answered this question before participating in the Collaborative Math Learning Labs. (See Appendix I for relevant survey questions.)

**Teacher Background and Demographics Survey**

This survey contains 14 questions regarding teachers’ job title and responsibilities, experience, degrees, identities, and languages spoken. (See Appendix J for a copy of this survey.)

**Research Design for the Current Study**

Building off the existing *Collaborative Math in Head Start Study*, this study narrowed in to investigate the role of coaching within the larger intervention. Table 5 summarizes the research questions, measures and data sources, participants, and analysis plan.
### Table 5. Summary of Research Design for the Current Study

<table>
<thead>
<tr>
<th><strong>Main RQ:</strong> How does math-focused coaching impact preschool teachers’ content knowledge, teaching practice, and dispositions (attitudes, beliefs, and confidence)?</th>
<th><strong>Participants:</strong> Coaches (n= 5), Lead and Assistant Teachers (n = 141)</th>
</tr>
</thead>
</table>
| **Research Questions** | **Measures and Data Sources**
*denotes new data to be collected | **Analytical Techniques** |
| RQ1 *What is Collaborative Math’s coaching model?*  
  a. Which components are most salient to the coaching process as reported by coaches, teachers, and project materials?  
  b. What are the qualifications and demographics of Collaborative Math coaches? | Project documents (handouts, forms, PowerPoint presentations, website text),  
Coach Survey*  
Teacher Survey | qualitative:  
content analysis,  
open coding,  
axial coding,  
memos |
| RQ2 *What is the unique contribution of coaching among other intervention inputs?*  
  a. After accounting for pretest scores, Learning Lab attendance, instructional leader involvement, coach assignment, and teacher demographics, do varying amounts of coaching predict shifts in knowledge, practice, and/or dispositions?  
  b. How do coaches and teachers describe shifts in knowledge, practice, and/or dispositions in relation to coaching? What other coaching related outcomes do they mention? | Coaching Fidelity survey responses,  
Teacher Demographics survey responses,  
ABC-PM survey results,  
EQUIP-M video scores,  
Coach Survey*,  
Teacher Survey responses,  
Group Coaching Logs,  
Instructional Leader Consultation around Group Coaching Log | quantitative:  
t-test  
Hierarchical Linear Modeling (HLM)  
Multiple Linear Regression (MLR)  
qualitative:  
a priori coding  
memos |
| RQ3 *What factors facilitate and inhibit the outcomes of the coaching process?*  
  a. What possible factors do coaches and teachers suggest?  
  b. Do instructional involvement, assigned coach, or teacher role predict outcome scores? | Coach Survey*,  
Teacher Survey,  
Coach Characteristics Survey*,  
Group Coaching Logs, Coaching Fidelity Surveys  
ABC-PM survey results,  
EQUIP-M video scores | qualitative:  
open coding,  
axial coding,  
memos |

**Participants**

Participants included the 179 lead and assistant teachers who consented to research as part of the *Collaborative Math in Head Start Study*. In addition, all 8 coaches who were involved in the Collaborative Math intervention were invited to complete online surveys with a final
sample size of 5 coaches. Each coach worked with 1-3 sites and paired with Collaborative Math Content Team staff to facilitate Learning Labs each cycle.

**Role of the Researcher**

The researcher for the present study is a former PreK-2 teacher who has also been employed part-time as a math coach with the Erikson Early Math Collaborative. She did not yet work as a coach during 2016-2017, the year the Collaborative Math intervention and *Collaborative Math in Head Start Study* data were collected for the proposed study. At that time she was an active member of the *Collaborative Math in Head Start Study* research team helping to refine measures and recruit participants. The researcher joined Collaborative Math as a coach the following year and worked in one Head Start site that had been in the control condition during 2016-2017. The 10 teachers and two instructional leaders she worked with at that site are likely among the participants; however, they are listed by their code numbers only in all data accessible to the researcher and therefore are not identifiable. By the time analysis occurred in 2019, the researcher was no longer working as a coach. Additionally, the majority of coach participants who were part of Collaborative Math in 2016-2017 were the researcher’s colleagues. For this reason, extra confidentiality measures are described below. Having worked as a coach as part of Collaborative Math affords the researcher unique insight to aid in data collection, analysis, and interpretation (Merriam & Tisdell, 2016).

**Validity and Reliability**

All researchers bring their own biases when interpreting data. To increase validity in analysis of the qualitative data in the current study, the researcher worked with a graduate student research assistant (“assistant”). Individually and together they practiced reflexivity, the "process of critical self-reflection on one's biases, theoretical predispositions, preferences, and so
forth” (Schwandt, 2014, p. 260). Before interpreting the data from participants, the researcher and assistant each completed the coach and teacher surveys in two ways: (a) how they would respond as former teachers and/or coaches, and (b) how they anticipated participants might respond. This allowed them to “bracket” their personal experiences and assumptions prior to viewing the data (Merriam & Tisdell, 2016). The researchers also each kept a weekly reflexivity journal, writing down their hypothesis in response to each of the research questions and tracking how their biases shifted as coding occurred. Documents were saved in a shared folder and read by the opposite researcher before each weekly meeting, and researchers openly disagreed about a finding if they thought the other was drawing more from their personal bias than from the available data. To increase validity, researchers also looked for data that supported contradictory conclusions from what they expected (Patton, 2014).

**Measures**

The present study involved a mix of data that had already been collected as part of the *Collaborative Math in Head Start Study* and new data. Table 6 provides a summary of all measures; the two new measures are described in detail below.
Table 6. Summary of Measures and Data Sources

<table>
<thead>
<tr>
<th>Existing Data</th>
<th>Data to be collected</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Attitudes, Beliefs, and Confidence in Preschool Mathematics (ABC-PM)</td>
<td>• Successes and Challenges Survey – Coaches (Coach Survey)</td>
</tr>
<tr>
<td>• Pedagogical Content Knowledge in Preschool Mathematics (PM-PCK)</td>
<td>• Coach Characteristics Survey</td>
</tr>
<tr>
<td>• Evaluating Quality Interactions in Preschool Math (EQUIP-M)</td>
<td>• Collaborative Math documents</td>
</tr>
<tr>
<td>• Group Coaching Log</td>
<td></td>
</tr>
<tr>
<td>• Instructional Leader Consultation around Group Coaching Log</td>
<td></td>
</tr>
<tr>
<td>• Coaching Fidelity Survey</td>
<td></td>
</tr>
<tr>
<td>• Successes and Challenges Survey – Teachers (Teacher Survey)</td>
<td></td>
</tr>
<tr>
<td>• Teacher Background and Demographics Survey</td>
<td></td>
</tr>
</tbody>
</table>

**Successes and Challenges Survey – Coaches (Coach Survey)**

This online survey mirrors questions from the teacher version of the Successes and Challenges survey to gain an additional coach perspective on the same topics. It also includes supplementary questions to obtain data about how coaches perceive Collaborative Math’s approach and their role, as well as how they are trained and supported. Prior to distribution, both surveys were piloted with five research colleagues as well as a newly hired coach who is not part of the sample. Surveys were revised based upon their recommendations before being sent to participants. A copy of the open-response survey questions can be found in Appendix K.

**Coach Characteristics Survey**

This online survey captured demographic and experience information about Collaborative Math coaches including teaching and coaching experience, degrees obtained, and languages spoken. A copy of the survey can be found in Appendix L.
**Official Collaborative Math Documents**

The researcher collected printed and digital materials for content analysis (Altheide, 1987) to answer Research Question 1 alongside survey response data. Documents included:

- a 17-page booklet of protocols used by coaches
- website text describing coaching from earlymath.ekrison.edu
- agendas, facilitator outlines, and slide decks from 6 Leadership Academies
- coaching-related handouts given to teachers and/or instructional leaders

Each document was screened for the terms “coach” or “coaching” in the title or document itself, or for related terms such as “planning” and “reflecting.” For example, a handout given to instructional leaders on “Creating a Plan for Collaborative Coaching” was included whereas a handout on “Inducting New Teachers into the Content” was not. The “Planning Template for maintaining a math focus at my site” was included because of the language, “Intentional/ Teaching. Teams plan together a math activity, they do it and then get together to reflect on what occurred.” Those that did not directly or indirectly reference coaching were placed aside to be revisited later if needed in order to reach saturation.

**Procedures**

**Recruitment**

Coaches were informed about the option of participating in the research during a regular monthly coach meeting in which supervisors left the room. Coaches had a chance to ask questions and were assured that all participation is voluntary. Once the study, procedures, risks and discomforts, and benefits were fully discussed and understood, the researcher shared consent forms with the option to check a box with yes or no regarding interest in participating. (See Appendix M for a copy of the consent form.) Coaches were asked to place their completed
survey in an envelope. The researcher then left the room to assure all decisions to participate are done without pressure and remain confidential.

Since the two coach supervisors also worked as coaches, they were consented in a similar process during an additional meeting. Former coaches who are no longer employed by Erikson Institute, and one coach who was absent from the meeting mentioned above, were contacted via email, told about the opportunity, and assured that all participation is voluntary. Interested participants were invited to schedule a phone call so that the study, procedures, risks and discomforts, and benefits could be discussed in full.

The researcher worked closely with a member of the Collaborative Math research team in order to maintain participant confidentiality and reduce bias due to prior relationships. This researcher opened the envelope to see the participant names and administered surveys. An anonymization scheme was created before data collection began and the researcher has access to only the code numbers, and not the names, of all participants. Identifying information is kept confidential from supervisors and other Erikson staff as well. Only select members of the Collaborative Math research team have access to the identifying file, which is stored on a password protected computer. Survey questions were programmed into the Survey Monkey platform. Participating coaches received an email from the collaborating research team member with a link to the survey along with their unique code number. Only this code, and no names, were entered into the survey.

**Confidentiality**

All researchers involved in the proposed study were required to complete the Collaborative Institutional Training Initiative (CITI) Program training on Human Subjects Research and follow Erikson Institute Institutional Review Board (IRB) guidelines. This includes
the faculty chair, researcher, graduate student assistant, dissertation committee members, and members of the Collaborative Math staff who support access to and understanding of previously collected data. New research for the proposed study was granted IRB approval January 9, 2019. The Collaborative Math in Head Start Study, from which the majority of the data originate, previously received Erikson Institute IRB approval and all data collection and storage procedures continued to ensure participants’ protection. Project staff removed all identifying information from coach logs, fidelity surveys, and other documents before sharing with the researcher.

Reports, publications, or presentations of this research will never include names or other identifying information about coaches, teachers, or Head Start sites. Code numbers or generalized text such as “teacher” or “coach” are used to further protect confidentiality. Answers from the Successes and Challenges Survey and Coach Characteristic Survey were analyzed separately in order to avoid identifying coaches based upon their background information. Access to survey data is limited to the researcher and graduate student research assistant. Results were not discussed with colleagues or supervisors until all analysis was complete, and then only in general terms.

All digital files are stored on a secured hard drive or a secured online resource that is protected by a password only available to project staff. Consent forms do not contain sensitive information such as birthdates or demographic information. Signed forms were scanned and saved on a password-protected server. Hardcopies are stored in a secured locked file, located in a locked office space at Erikson Institute and will be destroyed three years from the end of the study. Study partners (including Head Start and grantee staff) and coaches from Collaborative Math do not have access to research data.
Data Requests

In order to obtain existing data, the researcher wrote a formal request to Collaborative Math’s Assistant Director of Research. A Research Analyst prepared data by removing all identifiers and replacing teacher, coach, and center names with numerals. Information pertaining to any teacher who withdrew from the study was blacked out in coaching logs. Coach (n=5) and teacher (n=64) survey response data were cleaned and organized in an Excel spreadsheet. Logs and documents were converted into PDF files. Based on the criteria of two classrooms per center, there were a total of 141 coaching logs of varying lengths and levels of completeness: 89 Group Coaching Logs, 36 Instructional Leader Consultation Around Group Coaching Logs, and 16 Mixed Logs (coaches had the unanticipated option to create their own logs to jot down notes rather than use the form template).

After coding for Research Question 1, it became apparent that additional data about Learning Labs would be needed in order to contrast with the data about coaching as a further means of isolating the contributions of coaching. A second data request was submitted to obtain short surveys known as “exit slips” from the five Learning Labs as well as four questions related to Learning Labs from the teacher survey (n=64).

Qualitative Analysis

Analysis began with qualitative data for each of the three research questions in Fall 2019. Research Question 1 relies on only qualitative data and asks: What is Collaborative Math’s coaching model? Specifically, (a) Which components are most salient to the coaching process as reported by coaches, teachers, and project materials? and (b) What are the qualifications and demographics of Collaborative Math coaches? Data sources for this question included official
Collaborative Math project documents (n=72), Teacher Survey responses (n=64) and Coach Survey responses (n=5).

The qualitative portion of Research Question 2, *What is the unique contribution of coaching among other intervention inputs?* asks: *How do coaches and teachers describe shifts in knowledge, practice, and/or dispositions in relation to coaching? What other coaching-related outcomes do they mention?* And Research Question 3 is also a qualitative question asking *What factors facilitate and inhibit the outcomes of the coaching process? and What possible factors do coaches and teachers suggest?* Data sources for Research Question 2 and Research Question 3 included the same Teacher and Coach Survey responses as well as Group Coaching Logs (n=140), and Instructional Leader Consultation around Group Coaching Logs (n=70). Logs consisted of a purposive sample of 2 teaching teams per site for each coaching cycle 1-5.

**Team Analysis**

Another doctoral student served as the graduate student research assistant (“assistant”) to conduct qualitative analysis alongside the student researcher in exchange for internship credit. She is a former preschool teacher and worked part-time as a Research Assistant with the *Collaborative Math in Head Start Study.* Thus she had familiarity with the intervention as a whole, but none with coaching.

To acquaint herself with the project, the assistant read the literature review, theoretical frameworks, and research questions. She then recorded her hypothesis about the research questions based upon her own experience and understanding of the literature before reading the researcher’s hypothesis included in the proposal. The assistant also reviewed the coach and teacher survey tools and wrote about anticipated responses. Since the researcher worked as a coach, she wrote about how she would personally respond to coach survey responses and also
how she thought her colleagues might. These early reflexivity procedures shed light on the perspectives each member of the research team brought to the analysis, and were collected in a document folder that could be referred to and discussed each week throughout the coding process.

Over the course of three months, the researcher and assistant met weekly to discuss preliminary findings, assess code agreement, refine code definitions, troubleshoot software complications, create an audit trail in a secure document, and assign next steps. The use of memos and weekly meetings allowed analysis to occur simultaneously along with coding.

**Dedoose Analysis Software**

All qualitative data sources were uploaded into Dedoose version 7.0.23, “a web application for managing, analyzing, and presenting qualitative and mixed method research data” (2016). In order to limit bias, qualitative responses to the coach surveys were uploaded first and coded, without any attachment to demographic information. Once coding was complete, demographic information was attached for analysis.

Coding and analysis proceeded in the order of the research questions. Coding data separately for each research question-- and thus eliminating distractions and reducing bias-- required the creation of three separate projects in Dedoose. In other words, the researchers could not see the codes from Research Question 1 when applying codes to data for Research Questions 2 or 3.

**Coding Process**

**Codebook**

First, the researcher populated a list of possible *a priori* (Schwandt, 2014) codes from the literature and her professional experience. Specifically, *a priori* codes for Research Question 1
were created based upon the review of the literature as presented in Table 3: Summary of Coaching in the Education Literature (page 42) and \textit{a priori} codes for Research Question 2 were inspired by Chen and McCray’s Whole Teacher Approach (2013). Research Question 3 had a few \textit{a priori} codes based upon hypothesis, but most were added from themes that emerged from data. Codes were organized into a code tree in Dedoose and defined with brief descriptions and synonyms. Final codebooks for each research question are available in Appendix N.

Next, the researcher and assistant separately highlighted relevant chunks of data and assigned codes. New codes were added as additional themes emerged within data. Some of the original codes were merged, further divided into subcodes, or deleted. Quotes from participants that were strong examples to help define codes were added to the codebook descriptions as the researchers encountered them. Likewise, when possible, \textit{in vivo} codes using the participant’s own language were created. Throughout the process, the researchers applied a filter setting in order to blind themselves to each other’s codes. A feature that counts the number of times each code is applied allowed researchers to consider if there were codes they were applying too much or too little throughout the process in order to check for thoroughness and bias. Code co-occurrence matrixes were also employed to detect redundancy in codes or uncover related themes. The research question was clearly displayed throughout the process to keep researchers focused.

\textit{Memos}

As coding occurred, the researchers also used the embedded Dedoose memo feature to individually write about coding process thoughts, emerging themes within data, questions, confusions, surprising data, rational for new codes or unclear code applications, connections to literature, and connections to personal experience. This allowed the researchers to have an
ongoing conversation with the documents by jotting down “thoughts, musings, speculations and hunches” (Merriam & Tisdell, 2016, p. 174). Each memo is linked to either text in data or a specific document, and tagged with searchable themes to aid in organization. Both researchers reviewed memos in order to populate agenda items for weekly meetings.

Validity and Reliability

Both researchers applied codes to the same data and discussed differences during meetings, since “[d]efinitions become sharper when two researchers code the same data set and discuss their initial difficulties…” (Miles et al., 2019, pp. 84-5). A Dedoose feature to assess inter-rater reliability was employed to determine which codes were applied with the least agreement and these were verbally discussed so that each coder could further align in thinking and the codebook could be further refined. After the initial coding for each research question, data were reviewed a second time to improve consistency and include newly created codes.

Saturation

Coding ceased either when all available data were reviewed or the researchers agreed the process had become redundant and they had reached saturation, “the point at which… no new information, insights, or understandings are forthcoming” (Merriam & Tisdell, 2016, p. 183). The researcher used the coding process, memos, and discussions to write up preliminary findings and ongoing wonderings for each research question. The decision to move to the next research question was determined once both researchers agreed with these findings and all wonderings were resolved. Triangulation (Merriam & Tisdell, 2016) occurred by corroborating responses from teachers, coaches, logs, and official Collaborative Math documents. The researcher noted themes that surprised her and looked for data that countered her initial hypotheses.
Analysis

Once coding was complete, demographic information was added using the descriptors feature in Dedoose. Teacher descriptors included lead (n=31) or assistant (n=33) and center number (n=13). Coach descriptors included years of experience (8-11 years). Document descriptors included audience (internal, external), coaching cycle number (1-5), and type (handout, PowerPoint, protocol, other). In addition to memos and discussion among researchers, data were further analyzed by sorting code applications based upon descriptors. The three different perspectives (teachers, coaches, and official documents) were contrasted and compared, as well as the differing experiences of assistant and lead teachers. Keeping in mind the nested quality of the quantitative data, the researchers also looked for patterns in the qualitative data showing similarities and differences from teachers at the same center.

Quantitative Analysis

This section first explains the data preparation procedures, including accounting for attrition and the use of multiple implementation. It then details the guiding analytic questions and their related procedures including Hierarchical Linear Modeling (HLM).

Data Preparation

Data were downloaded from Survey Monkey or manually entered into Microsoft Excel by members of the Collaborative Math in Head Start Study research team. Once obtained for the current study, it was combined and cleaned using Excel, and then explored and analyzed using IBM SPSS Statistics Version 23 and HLM Version 7 Student Edition from Scientific Software International, Inc.
Attrition

Attrition refers to a loss of participants from an initial sample after random assignment has occurred. Participants may withdraw from a study or opt out of select measures, resulting in missing data. This is particularly common in longitudinal studies when participants are asked to complete measures more than once with time in between. Attrition may introduce bias, or results that deviate from the true impact, especially if the loss of participant data cause the intervention and comparison groups to no longer differ randomly.

The original sample from the Collaborative Math in Head Start Study contained 179 participants. Inclusion in the present study required participants to meet the following criteria: (a) they remained in the study until the conclusion; and (b) they have data for at least one teacher outcome measure at baseline or spring. These conditions allow the present study to understand the coaching model as intended by the Collaborative Math intervention while focusing on the amount of coaching. For example, in the intervention condition, six teachers withdrew before the intervention began and four left after Cycle 1. Including their incomplete attendance in analysis makes it appear as if less coaching appeared overall and creates too much bias. Furthermore, these criteria also make the quantitative sample more similar to the qualitative sample since surveys were administered at the intervention’s conclusion. Finally, this approach differentiates the present study from the larger study, thus allowing for increased knowledge.

From the original 179 participants, 37 participants (21%) withdrew before the study concluded. Thirty teachers ceased employment at their centers; five teachers switched to positions in toddler classrooms at their center and were no longer eligible; one teacher was promoted to a leadership position at their center; and one teacher took maternity leave from November until March. The intervention group lost 13 participants and the comparison group
lost 24 participants. In addition, one teacher from the intervention cohort did not have any data for EQUIP-M or ABC-PM at baseline or spring.

After both criteria were applied, the resulting sample contains **141 participants with 72 in the intervention condition and 69 in the comparison condition**. In total, 113 participants have data available for both teacher measures at both baseline and spring time points while 28 participants teachers are missing either EQUIP-M or ABC-PM but not both.

An independent sample t-test was used to compare the 38 participants who were excluded from final analysis and the 141 participants who remained. This was not significant for: EQUIP-M Baseline, \( t(142) = -0.014, p = 0.989 \); Attitudes Baseline \( t(160) = 0.969, p = 0.334 \); Confidence baseline, \( t(160) = -0.662, p = 0.509 \); EQUIP-M Spring \( t(127) = 0.858, p = 0.224 \); Attitudes Spring \( t(123) = 1.087, p = 0.279 \); and Confidence Spring \( t(123) = 0.466, p = 0.642 \). In addition, Little’s MCAR Test was not significant (\( p > .05 \)) confirming that there is no systematic bias in missing data (McKnight et al., 2007). Attrition occurred across centers in both treatment and comparison conditions, with an average of 1.4 teachers per center withdrawing from the study. The attrition group included 17 lead teachers and 21 assistant teachers. Overall, the intervention and comparison groups remain similar across demographic variables, as reported in Table 7. Therefore, the attrition was random and not linked to a particular variable.
Table 7. Teacher Demographics after Attrition

<table>
<thead>
<tr>
<th>Gender</th>
<th>Intervention (n = 72)</th>
<th>Comparison (n = 69)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>93%</td>
<td>88%</td>
</tr>
<tr>
<td>Male</td>
<td>2%</td>
<td>10%</td>
</tr>
<tr>
<td>Prefer not to answer</td>
<td>---</td>
<td>1%</td>
</tr>
<tr>
<td>Race/Ethnicity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>American Indian / Alaskan Native</td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td>Asian / Pacific Islander</td>
<td>1%</td>
<td>4%</td>
</tr>
<tr>
<td>Black / African American</td>
<td>36%</td>
<td>39%</td>
</tr>
<tr>
<td>Hispanic / Latinx</td>
<td>36%</td>
<td>36%</td>
</tr>
<tr>
<td>White / Caucasian</td>
<td>13%</td>
<td>18%</td>
</tr>
<tr>
<td>Other</td>
<td>8%</td>
<td>1%</td>
</tr>
<tr>
<td>Prefer not to answer</td>
<td>2%</td>
<td>---</td>
</tr>
<tr>
<td>Missing</td>
<td>11%</td>
<td>11%</td>
</tr>
<tr>
<td>Education</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High School degree or equivalent</td>
<td>2%</td>
<td>---</td>
</tr>
<tr>
<td>Some college but no degree</td>
<td>10%</td>
<td>13%</td>
</tr>
<tr>
<td>Associate degree</td>
<td>18%</td>
<td>24%</td>
</tr>
<tr>
<td>Bachelor degree</td>
<td>40%</td>
<td>52%</td>
</tr>
<tr>
<td>Graduate degree</td>
<td>21%</td>
<td>7%</td>
</tr>
<tr>
<td>Missing</td>
<td>8%</td>
<td>3%</td>
</tr>
</tbody>
</table>

As previously noted, the final sample contains participants who still have missing data, and the What Works Clearinghouse Handbook (WWC; 2014) also considers this part of attrition. WWC looks at the relationship between *overall attrition*, the percentage of all participants with no outcome data, and *differential attrition*, the difference between percentages of attrition in the intervention group and the comparison group. If the overall attrition is high, it may be offset by low differential attrition; if the differential attrition is high, it may be offset by low overall attrition. WWC defines high attrition as above 0.05 standard deviations, and provides a table to assess the level when considering both types of attrition together. A conservative threshold is used when the reason for attrition might be related to the outcome variable and an optimistic threshold is used when the reason for attrition is external.
For EQUIP-M, a total of 124 participants have outcomes scores resulting in an overall attrition of 30.7%. The differential attrition was calculated by subtracting the percentage of participants without EQUIP-M outcome data in the intervention group (26.74%) from the percentage of participants without outcome data in the comparison group (34.4%). The result of 7.66% is above WCCs’s cautious boundary of 4.1% but below the optimistic boundary of 8.2% and is therefore considered low attrition.

For ABC-PM, a total of 124 participants have outcome data resulting in an overall attrition of 30.7%. While this is the same quantity as for EQUIP-M, only 3 participants are missing outcome data for both teacher measure so there is little overlap. The differential attrition is 5.44% (27.9% in the intervention group minus 33.34% in the comparison group), which is above WCCs’s cautious boundary of 4.1% but below the optimistic boundary of 8.2% and is therefore considered low attrition.

Multiple Imputation

While the attrition is low, a decision still must be made regarding the missing values in the dataset for the final sample. Traditionally, researchers have dealt with missing data through methods such as listwise and pairwise deletion to simply ignore missing cases when running analysis. Another popular approach is to calculate new values for the missing ones that maintain the same mean for the variables but do not capture plausible variability. Unless less than 5% is missing, these methods introduce too much bias and may damage internal and external validity (Jeličić et al., 2009; Peugh & Enders, 2004). Instead, statisticians recommend methods that maintain variability such as Maximum Likelihood Estimation and Multiple Imputation (Allison, 2002; Little & Rubin, 2002).
Defining the mechanism is the first step in determining how to handle the missing data. Following Rubin’s (1976) “mechanisms” for classifying missing data, the mechanism for the present study is assumed to be “Missing at Random” (MAR), the middle option on his continuum of three mechanisms. Due to the nature of data collection, teachers who are missing attitude outcomes are also missing confidence outcomes. Therefore, the missing values are not considered “Missing Completely at Random” (MCAR) which would be the case if there were absolutely no patterns. While it may be possible that teachers with poor attitudes about math or those who have less confidence in math teaching did not take ABC-PM because of this, it is impossible to know for sure without those data points. Thus, it is assumed that the reason data are missing is not known to be related to the values of the measure and thus they are not “Missing Not at Random” (NMAR). The exploration of attrition detailed above also supports the assumption that the data are MAR.

Multiple Imputation (MI) was chosen for the present study because of the high overall percentage of missing cases and its favorable reputation among statisticians for use in longitudinal studies (van Buuren 2018; McKnight et al., 2007). Using probability, MI determines new values based upon the available data through a user-specified number of iterations of chain equations (Schafer & Graham, 2002). As a result, variability is maintained in a complete dataset that is an aggregate of multiple simulations to find the best fit.

Using the Impute Missing Data Values function, SPSS scanned the data and selected Markov chain Monte Carlo (MCMC) at the optimal method. MCMC uses linear regression in its algorithm, and is best when there is a random rather than monotone pattern of missing data. Thirty iterations were chosen based upon Bodner’s (2008) recommendation to match the number of iterations to the percentage of data missing. While five iterations are the default in SPSS and
10 iterations are generally accepted, increasing the quantity of iterations increases precision (Schafer & Graham, 2002). This resulted in 31 complete datasets: the original plus 30 new datasets. The output for subsequent analysis in SPSS includes results for all datasets so that they could be reviewed and compared (Heymans & Eekhout, 2019), as well as pooled results from the 30 iterations combined. Pooled results are reported, unless otherwise noted.

**Analytic Procedure**

Analysis of quantitative data was guided by three questions with related procedures: (a) Were intervention and comparison groups similar at baseline? (b) Did the overall intervention shift teachers’ outcome scores? and (c) Does the amount of time spent in planning, lesson, or reflecting conversations impact teacher outcomes? Before conducting each analytic procedure, relevant assumptions will be tested and reported.

**T-Test to Examine Groups at Baseline**

To answer the first question, an independent-samples t-test was chosen due to having a continuous dependent variable (teacher measure spring scores), an independent variable with two categorical, independent groups (condition), and independence of observations (no teachers are in both groups). Establishing that groups were similar on all three measures at baseline is necessary in order to support the results of the next procedure.

**Hierarchical Linear Modeling to Examine Effect of Cohort Randomization**

Second, *did the overall intervention shift teachers’ outcome scores?* Since coaching was an integral part of the intervention designed to be intertwined with Learning Labs and instructional leader support, it makes sense to first test for differences between teachers in the comparison and intervention groups before focusing in on coaching. Due to the nature of the data with teachers nested within centers, the present study employed 2-level Hierarchical Linear
Modeling (HLM; Raudenbush & Byrk, 2002), a type of ordinary least squares regression often used for analyzing education data. This is necessary since teachers working together at the same center are likely to be more similar to each other compared to teachers in different centers due to the fact that they share environments, work expectations, cultures, leaders, and so forth. While most statistical models assume that errors are independent, HLM accounts for the correlation between residual scores of teachers at the same center and helps to explain the variance.

The linear mixed models function in SPSS was used to conduct HLM (Heck et al., 2014). SPSS was chosen over HLM software to accommodate the dataset with multiple imputations since HLM software cannot produce pooled outcomes. In order to aid in interpretation of intercept and slope parameters, Level 1 predictor variables were group mean centered (centered within cluster) and Level 2 predictor variables were grand mean centered (Kreft et al., 1995). For example, the average amount of planning time for the center at which they teach was subtracted from each participant’s individual planning time to assign them a new group mean centered variable. Conversely, the average instructional leader involvement across the sample was subtracted from each participant’s center’s instructional leader involvement score. This approach was chosen since the dependent variables of interest are at Level 1 (Enders & Tofighi, 2007).

Additionally, Restricted Maximum Likelihood was selected as the estimation parameter because it has been found to be less biased with small samples compared to Maximum Likelihood (Heck et al., 2014; Albright & Marinova, 2010).

Model testing was guided by four possible steps: (a) a null model to compare the amount of variance between and within centers; (b) a random intercepts model to test the relationship between level 1 predictor variables and the outcome variable; (c) a means-as-outcome model to test the relationship between level 2 predictor variables and the outcome variable; and (d)
intercepts-and-slopes-as-outcomes model to test the interaction of level 2 and level 1 predictor
variables (Anderson, 2012; Woltman et al., 2012). Where applicable, this series was followed for
each of the three outcome variables for both this question about study condition and the
preceding question.

Null Model

The first model is considered “null” or “empty” because it does not have any predictor
variables; it is the same as an Analysis of Variance (ANOVA) with random effects. Teachers
were at level 1 and centers were at level 2 with the equation as follows:

Level-1: \( Y_{ij} = \beta_{0j} + r_{ij} \)

where the outcome variable \( Y \) (EQUIP-M, attitude, or confidence score) for teacher \( i \) nested in
center \( j \) equals \( \beta \) the average outcome in center \( j \) plus an individual-level error \( r_{ij} \). (within group
variance in teacher scores). To account for a possible effect caused by center clustering, a
separate equation is specified:

Level 2: \( \beta_{0j} = \gamma_{00} + u_{0j} \)

where \( \gamma_{00} \) is the average outcome score for all teachers in the sample and \( u_{0j} \) is the center specific
effect (between group variance in teacher scores). Through substitution the combined null model
becomes:

Combined: \( Y_{ij} = \gamma_{00} + u_{0j} + r_{ij} \)

The output was then used to calculate the intraclass correlation coefficient (ICC) for each
teacher measure by dividing the level 1 residuals by the total combined residuals from level 1
and level 2 (Garson, 2013). The ICC is a ratio of between group scores to total variation that
estimates how strongly two members from the same group resemble each other. A large ICC
(close to 1) indicates that variability in teacher outcomes between different centers is large and
the variability in teacher outcomes within the same center is small; that is teachers are more similar to their immediate colleagues at the same center than they are to teachers at other centers. A small ICC (approaching zero or negative) means the opposite: there is little variation among different centers and greater variability among teachers within the same center; that is, teachers are more similar to teachers at other centers than they are to their immediate colleagues at the same center.

A high ICC necessitates the use of HLM because the assumption of independence has been violated for similar regression models. An ICC greater than 0.05 has shown that HLM will provide more information than a regression model (Nezlek, 2011; Goldstein, 2011) but there is no consensus on a cut-off point (Woltman et al., 2012). It is also considered best practice to model data closely to how they appear in the real world (Hayes, 2006; McCoach & O’Connell, 2016) so HLM was used even when ICCs were low.

**Random Intercepts Model**

Next, predictor variables were added to this model to examine if the study condition was a significant predictor of spring outcome scores after controlling for baseline scores (similar to an ANCOVA without the assumption of independence). Center is a random effect because centers that participated in the study vary randomly from the larger population of Head Start sites, and the present study is interested in estimating the variance introduced into the model due to center clustering (Snijders, 2005). This between center variance is modeled by letting the intercepts and slopes vary since some centers have higher average teacher scores than other centers (Hegedusa et al., 2013). All other variables are fixed because their beta coefficient is of interest for interpretation and they are either continuous or binary (Snijders, 2005). Center was
entered as a random grouping subject (level 2). Spring outcome scores were entered as the dependent variable $Y$ and baseline scores were entered as a fixed effect covariate at level 1:

$$Y_{ij} = \beta_{0j} + \beta_{1j} (Baseline)_{ij} + r_{ij}$$

**Means-as-Outcome Model**

Then study condition was entered as a fixed effects covariate at level 2 since randomization into conditions occurred by center, not by individual teachers.

$$Y_{0j} = \gamma_{00} + \gamma_{01}(Study\text{Condition})_{j} + u_{0j}$$

$$\beta_{1j} = \gamma_{10} + \gamma_{11}(Study\text{Condition})_{j} + u_{1j}$$

Each predictor added at level one requires a new beta at level 2: the first is the intercept, and the second is for the fixed effect of baseline scores. $\beta_{0j}$ can be interpreted as the mean outcome score for center $j$ after controlling for baseline scores plus $u_{1j}$ between group variance.

**Hierarchical Linear Modeling to Examine Impact of Dosage**

The final questioning guiding quantitative analysis asks: *does the amount of time spent in planning, lesson, or reflecting conversations impact teacher outcomes?* This question focuses only on the 72 participants in the treatment condition who received varying amounts of coaching.

A similar 2-level HLM was created following the steps outlined above. First, a null model was run to calculate the ICC of the new sample, again with center as a random grouping subject (level 2) and spring outcomes scores as the dependent variable. Then predictors were added to the model. At level 1, baseline scores, planning time, lesson time, reflecting time, and teacher role were entered together as fixed effect covariates:

$$Y_{ij} = \beta_{0j} + \beta_{1j} (Baseline)_{ij} + \beta_{2j} (Planning)_{2j} + \beta_{3j} (Lesson)_{3j} + \beta_{4j} (Reflecting)_{4j} + \beta_{5j} (TeacherRole)_{5j} + r_{ij}$$
At level 2, Instructional Leader Involvement and Coaches were entered together as fixed effect covariates:

Level 2: $\beta_{0j} = \gamma_{00} + \gamma_{01}(ILinvolvement)_{j} + \gamma_{02}(Coach92)_{j} + \gamma_{03}(Coach93)_{j} + \gamma_{04}(Coach94)_{j} + \gamma_{05}(Coach95)_{j} + \gamma_{06}(Coach96)_{j} + \gamma_{07}(Coach97)_{j} + \gamma_{08}(Coach98)_{j} + u_{0j}$

$\beta_{1j} = \gamma_{10} + \gamma_{11}(ILinvolvement)_{j} + \gamma_{12}(Coach92)_{j} + \gamma_{13}(Coach93)_{j} + \gamma_{14}(Coach94)_{j} + \gamma_{15}(Coach95)_{j} + \gamma_{16}(Coach96)_{j} + \gamma_{17}(Coach97)_{j} + \gamma_{18}(Coach98)_{j} + u_{1j}$

$\beta_{2j} = \gamma_{20} + \gamma_{21}(ILinvolvement)_{j} + \gamma_{22}(Coach92)_{j} + \gamma_{23}(Coach93)_{j} + \gamma_{24}(Coach94)_{j} + \gamma_{25}(Coach95)_{j} + \gamma_{26}(Coach96)_{j} + \gamma_{27}(Coach97)_{j} + \gamma_{28}(Coach98)_{j} + u_{2j}$

$\beta_{3j} = \gamma_{30} + \gamma_{31}(ILinvolvement)_{j} + \gamma_{32}(Coach92)_{j} + \gamma_{33}(Coach93)_{j} + \gamma_{34}(Coach94)_{j} + \gamma_{35}(Coach95)_{j} + \gamma_{36}(Coach96)_{j} + \gamma_{37}(Coach97)_{j} + \gamma_{38}(Coach98)_{j} + u_{3j}$

$\beta_{4j} = \gamma_{40} + \gamma_{41}(ILinvolvement)_{j} + \gamma_{42}(Coach92)_{j} + \gamma_{43}(Coach93)_{j} + \gamma_{44}(Coach94)_{j} + \gamma_{45}(Coach95)_{j} + \gamma_{46}(Coach96)_{j} + \gamma_{47}(Coach97)_{j} + \gamma_{48}(Coach98)_{j} + u_{4j}$

$\beta_{5j} = \gamma_{50} + \gamma_{51}(ILinvolvement)_{j} + \gamma_{52}(Coach92)_{j} + \gamma_{53}(Coach93)_{j} + \gamma_{54}(Coach94)_{j} + \gamma_{55}(Coach95)_{j} + \gamma_{56}(Coach96)_{j} + \gamma_{57}(Coach97)_{j} + \gamma_{58}(Coach98)_{j} + u_{5j}$

Teacher demographic variables were also entered at level 1 but removed from the final model because they were not significant, did not improve the model fit as determined by pseudo R squared, and are not the focus of the study. These include race, gender, the number of years working at their center, the number of years working with young children, and highest level of education. The models were also run with planning, lesson, and reflecting variables combined into a single variable of the total amount of coaching. Results were similar so they are not reported.
CHAPTER FOUR

RESULTS

The purpose of this chapter is to present the results of qualitative and quantitative analysis for each of the three research questions in order to answer the question: How does math-focused coaching impact preschool teachers’ content knowledge, teaching practice, and dispositions (attitudes, beliefs, and confidence)? Participant survey responses and log notes have been left in their original form whenever possible with a few exceptions using brackets to clarify meaning. The participant numbering system created by Collaborative Math researchers has been retained with teachers (n=64) ranging from 404-988 and coaches (n=5) ranging from 20-25.

Research Question 1: What is Collaborative Math’s Coaching Model?

RQ1a. Which Components are Most Salient to the Coaching Process as Reported by Coaches, Teachers, and Project Materials?

Collaborative Math’s coaching model is complex and dynamic, as symbolized by the variety of descriptors used to modify the word “coaching” found within the document data including presentation slides, participant handouts, coaching protocols, and website text. These descriptors are also triangulated by examples and comments in the surveys and logs from coaches and teachers. Terms used include “instructional,” “cognitive,” “content-focused,” and “group” which are also found in the literature about coaching in education reviewed for this study. Additionally, the unique phrase “collaborative coaching” is found in Collaborative Math
intervention materials but not in the existing literature. This section first describes the model and then explores the most salient components found within the data.

**Coaching Model Summary**

Borrowing the same “menu” format to organize details about coaching used in Chapter 2: Review of the Empirical Literature, findings about the Collaborative Coaching model are summarized in Table 8. These findings illuminate the approach undertaken by the Erikson Institute’s Early Math Collaborative working in 27 Chicago Head Start centers from September 2016 until April 2017 as part of the Collaborative Math intervention.

Collaborative Coaching is led by highly qualified coaches with master’s degrees, prior classroom teaching experience, and prior coaching experience. The majority are bilingual English and Spanish speakers. Training for coaches involves printed materials (protocols to guide conversations and the *Big Ideas of Early Mathematics* textbook to reference math content), collaboration with colleagues (monthly meetings with all coaches, monthly reflective supervision with a lead coach), occasional external workshops and conferences, and a climate in which coaches frequently share resources and reach out for support.

Participation in coaching is “center-wide” and required, involving all teachers who work in a classroom with children ages 3-5 including lead, assistant (paraprofessionals, aides) and instructional leaders (directors, education coordinators). Coaching is conducted on-site and builds upon content learned in workshops called Learning Labs that focus on “big ideas” (key math concepts for children to understand) and “teaching interactions” (key pedagogical moves to help teachers highlight the “big ideas” for children).
### Table 8. Collaborative Coaching Model Summary

<table>
<thead>
<tr>
<th><strong>Who is the coach?</strong></th>
<th>University partner, expert (master’s degree, prior classroom teaching experience and prior coaching experience), majority bilingual English/Spanish</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Who participates?</strong></td>
<td>Lead teachers, assistant teachers, instructional leaders (Director, Education Coordinator, etc.) in Head Start; “center-wide” = required for all teachers working in classrooms with children ages 3-5</td>
</tr>
<tr>
<td><strong>Modes</strong></td>
<td>Onsite</td>
</tr>
<tr>
<td><strong>Role of a coach</strong></td>
<td>Promote compliance with compassion</td>
</tr>
<tr>
<td><strong>Training for a coach</strong></td>
<td>Protocols, published resources (i.e. <em>Big Ideas</em> book), monthly group meetings, monthly individual supervision, informal colleague support, occasional external training</td>
</tr>
<tr>
<td><strong>Related coaching philosophies (and their key focus)</strong></td>
<td>Content-Focused Coaching, (pedagogical content knowledge), Practice-Based Coaching (teaching practices), Cognitive Coaching (reflection and autonomy)</td>
</tr>
<tr>
<td><strong>Focus</strong></td>
<td>Math content (“big ideas”), “teaching interactions,” “center-wide change”</td>
</tr>
</tbody>
</table>
| **Coaching cycle components** | 1. Planning Conversation  
2. The Lesson (sometimes called Observation)  
3. Reflecting Conversation |
| **Dosage**           | Duration: 8 months for full intervention; coaching for 6 months  
Frequency: 5 Cycles (about 1x per month)  
Intensity: Target of 45 minutes for Planning & Reflecting Conversations  
Actual: 45 minutes Planning (ranging 10-90 minutes); 42 minutes Reflecting (ranging 10-75 minutes) |
| **Coaching strategies** | Planning, role-play, practice new skills, modeling, data collection, feedback, relationship building |
| **Related activities** | Learning Labs, Instructional Leader Consultations, Leadership Academies |

The role of the coach is to assist teachers in complying with the goal of the project to create “centers of excellence in mathematics where quality early math instruction is fostered, celebrated, and sustained” through planning for, enacting, and reflecting upon common “research lessons.” Coaches facilitate conversations by supporting teachers to build confidence in math teaching and fostering collaboration among colleagues. During planning, coaches help teachers:  
(a) review “big ideas;” (b) choose “interactions;” (c) decide what data to collect during the
lesson; (d) determine logistics including location and materials; and (e) rehearse through role-play. Coach involvement during lessons ranges along a continuum from observing without interrupting, to sporadically assisting (often in the form of a question), to modeling all or part of a lesson while the teacher observes. Reflecting conversations begin by highlighting moments when teachers activated the “big ideas” with children as well as missed opportunities. Reflecting conversations conclude with plans for how teachers will continue supporting one another to foster math learning in their classroom.

The coaching model’s guiding philosophy has roots in Cognitive Coaching (Costa & Garmston, 1994) with question-driven protocols and reflection, while balancing this with the need for feedback around math content as influenced by Content-Focused Coaching (West & Cameron, 2013; West & Staub, 2003). Thus, the approach is similar to Knight’s (2018) use of “dialogical coaching” to balance asking and telling as part of Instructional Coaching. The early childhood setting, group coaching format, and discussion of particular teaching practices (“interactions”) make it similar to Practice-Based Coaching (Artman-Meeker et al., 2015; Snyder et al., 2015) although the two approaches have developed separately. The emphasis on collaboration around early childhood math content makes Collaborative Coaching unique.

The Collaborative Math intervention begins in September with a Learning Lab, and each lab is followed by a related coaching cycle with the exception of the final lab in April. Thus, coaching occurs in a frequency of five cycles approximately once per month spread over a duration of six months from October until April. Each cycle includes a planning conversation, the lesson (sometimes also referred to as “observation” or “enactment”), and a reflecting conversation. The model design intends for conversations to last about 45 minutes and actual averages found 45 minutes per planning conversation (ranging 10-90 minutes) and 42 minutes
per reflecting conversation (ranging 10-75 minutes).

Finally, instructional leaders join with at least one classroom for the full coaching cycle (planning, lesson, reflecting) for each of the five cycles. They meet with coaches during Instructional Leader Consultations before and after each conversation to debrief, plan, and grow their own skillset toward sustaining the work at their center once coach visits conclude at the end of the intervention. Instructional leaders also attend Learning Labs alongside teachers, as well as additional Leadership Academies to further deepen their understanding of math content as well as ways to support their teachers.

**Salient Components of the Collaborative Math Model**

A complete list of possible model components that emerged from the data along with definitions and example quotations is available in the Codebook for Research Question 1 in Appendix N. From this list, components were then sorted and categorized in search of relationships. Components were determined to be salient by considering the frequency of code application, the mention of components across data sources and participant groups, and the level of detail used to describe them. After this process, three overarching themes emerged:

1. An emphasis on math content and teaching interactions through planning.
2. A mix of questions and direct suggestions from coaches.
3. A group format that promotes collaboration among colleagues.

Each theme functions as an umbrella to capture further details of the model and is expanded upon below.

**Emphasizes Math Content through Planning**

A focus on specific math content is a salient component of the model as reported by participants, and as described in Collaborative Math materials. In the literature, Content-Focused
Coaching includes the coach and teacher planning together as a key component (West & Cameron, 2013; West & Staub, 2003) and this also arose as a salient feature of the Collaborative Math model. Collaborative Math materials both directly and indirectly show the importance of planning, and this emphasis is also reflected in the data where frequency counts for teacher and coach survey comments about planning are higher than for observations or reflecting conversations. Participants also repeatedly discuss coaching strategies used during planning sessions including role-play and determining specific types of “interactions” teachers will use to connect with children in math rich moments. Additionally, data are collected during the observation to determine if the lesson went as planned and used to guide reflecting conversations. Each of these major model components will be explored in detail below.

**Math Content.** There are frequent references to math content across sources including mention of “the math,” specific math topics such as “number sense,” activities and lessons such as “People Sort,” and especially the term “big ideas.” Big ideas are statements that “map the key math concepts young children need to explore between the ages of 3 and 6,” according the Early Math Collaborative website and detailed in the book the *Big Ideas of Early Mathematics* (Brownell, 2014). Each intervention participant receives a copy of the book and each Learning Lab focuses on 2-3 related “big ideas.” For example, three “Big Ideas about Sets” include: (a) “Sets can be compared and ordered;” (b) “The same collection can be sorted in different ways;” and (c) Attributes can be used to sort collections into sets.” (See Appendix O for a full list.) The 26 “Big Ideas” align with Common Core State Standards (2010) and meet three criteria outlined by Clements and Sarama (2008): “mathematically central and coherent…consistent with children’s thinking … [and] generative of future learning.”
Project materials and coaches discuss developing teachers’ understanding of mathematical content so that teachers can recognize and highlight it when engaging with children. For example, Slide 20 from Leadership Academy 1 is titled “People Not Programs” with the first bullet point “Focus on teaching important content well.” Coach 22 states there are “two main goals” of the project: “One is to help the teachers have better mathematical understanding and secondly it is to help teachers implement that understanding through intentional thoughtful classroom math work.” Coach 24 similarly explains her role: “I work with early childhood teachers to help them understand the big math concepts that children are creating.”

Teachers also notice this emphasis on the content. Teacher 882 said they “really like the way the coach continuously referred us to keep the Big Ideas at the forefront of what we were doing with the math activities,” and Teacher 988 reported that their coach “really helped us understand the math.” Teacher 924 summarizes the project, writing: “Through the coaching experience, our team became more math hungry for the children.”

**Planning.** The Collaborative Math coaching model is designed with three main points of contact between the coach and teachers as depicted in a slide from the introductory Leadership Academy in Figure 8: (a) Planning Conversation, (b) Observation (also sometimes referred to in documents as “The Lesson”), (c) and Reflecting Conversation.

In their survey response, Coach 22 describes each part of a coaching cycle in detail. First, teachers attend a workshop called a Learning Lab: “The Collaborative Math coaching model involves teachers working with a coach on implementing lessons/activities around math content that was learned/discussed at a common learning lab experience.” Then coaches conduct site visits for Planning Conversation:
The coach meets with the team of teachers in a given classroom to plan a lesson or activity in depth, think about the math they would like children to engage in, as well as their actions and behaviors to help support the children.

This is followed by an Observation: “The coach then observes the lesson and takes notes/data regarding the teachers' goals.” The last step is a Reflecting Conversation: “Finally, the team meets together to discuss how the activity went in terms of their goals, plan on how to further support the children's thinking around that content, and how the team can support each other.”

Figure 8. “The Overall Coaching Process”

While the similar sizes of the triangle and circle in Figure 8 suggest that each component has equal weight, a focus on planning emerges from the data both in official documents and participant comments from coaches and teachers. For example, the second bullet point from the Leadership Academy slide mentioned above states: “The real work is learning how to plan (at all levels) very, very well (collaboration helps).” In addition to explicit emphasis on planning like this example, there are also less direct, perhaps subconscious, examples of planning having
greater focus in the Collaborative Coaching model design. For example, the Group Coaching Protocol: Planning Conversation extends slightly beyond one page with 28 lines of text whereas the Group Coaching Protocol: Reflecting Conversation consists of six lines of text.

Likewise, when asked to describe the coaching model, Coach 24 places an emphasis on planning throughout the coaching process and as the ultimate goal of the model:

It is an ongoing set of learning cycles that have 3 points of contact. A planning conversation, an enactment of the math experience that was planned with someone collecting data that was decided upon during the planning conversation and a reflective conversation. The goal of the model is to help teachers become better planners of math experiences for children with clear goals.

Moreover, coaches are expected to complete logs during both planning and reflecting conversations; within the data, logs for planning conversations have more detailed notes compared to reflecting conversation logs.

When asked about the role of their coach, teachers repeatedly discuss how they worked together with their coach to think through an activity before involving children in the classroom.

Through coaching my team had time to plan for math lessons. Normally the team is so busy with so much that we don't get enough time to sit down and plan specifically for math lessons… (Teacher 664)

I was always asked how I would prepare for an activity. The coach would fine tune my words and introductions to an activity. (Teacher 744)

In addition to preparing for classroom teaching, the planning conversation is also an opportunity for teachers to review math content. Each coaching cycle focuses on a specific math experience that was introduced during the preceding Learning Lab for all participating teachers to try in their classroom. The protocol for coaches includes “clearing up misconceptions about the Big Ideas” as one purpose of the planning conversation, and the first question on the log is: “What Big Ideas do we want children to have a chance to wrestle with during this activity?”
Teacher Interactions/Language. Next, teachers consider what they will say and do to help bring out this “big idea” for children. The use of “Teacher Interactions to Build Mathematical Thinking” from a handout defined by the Early Math Collaborative was another salient component of the coaching model (see Appendix P for a copy of this handout with definitions and examples). Teacher Interactions include specific pedagogical choices such as “use descriptive language,” “wait,” and “re-voice.” The coach protocol states: “Help teachers identify the interactions they will use to scaffold the students’ thinking around the Big Ideas (Use the Teacher Interaction sheet).”

While documents and coaches use the term “interactions,” teachers conceptualize this as language choice:

I became more aware of utilizing math language to provoke children thinking in math. (Teacher 404)

I learned to use descriptive language with the children. (Teacher 979)

We learned some new math terminology to use with the children. (Teacher 898)

Using the correct language so students could benefit more. (Teacher 817)

We were able to set up activities and use math language that we were not used to using. (Teacher 821)

These comments show teachers’ recognition of the Collaborative Math coaching approach’s focus on verbalizing mathematical ideas during lessons and activities with young children.

Role-Play. Next, teachers practice using and refining the interaction they selected through role-play with colleagues during the planning conversation. Each teacher takes a turn pretending to lead the lesson with the materials in front of them, and the other teacher(s) and coach act as children. Coach 24 defines it as “having teachers rehearse as if they are in front of students.” The Collaborative Math Coaching Protocol defines this strategy as follows:
Get teachers to practice and rehearse what they will say to the children to introduce the activity, to implement the activity, to scaffold children’s thinking and to conclude the activity.

Teachers describe this strategy in their own words:

I was able to choose [sic] the activities that I wanted to do with the children my coach was helpful and we would practice doing the activities on each other and say what we thought of what we had done. (Teacher 500)

She was able to show us how to implement new knowledge with the students in the classroom by role-playing and answered any questions we may have. (Teacher 690)

And coaches describe their use of the role-play strategy with teachers:

I hope to bring out the big ideas more in both planning and reflection conversations. I hope to do more role-playing with teachers so that they are more comfortable with doing the work and have more information on how to apply their learning. (Coach 20)

As they think aloud about what the activity will look and sound like, I ask questions about how the actions or words the teacher uses will help bring out that big idea. It's also helpful for teachers to role-play leading the activity, as well as anticipate what the children will say/do. (Coach 25)

Overall, role-play is a strategy to transfer new knowledge and planning ideas to teaching application. It offers teachers an opportunity to physically practice the language, actions, and materials they will use with children and receive feedback from teaching peers and their coach. The group format allows teaching colleagues to take on the role of students, and in doing so they can anticipate how children may react. By taking turns leading the rehearsal during role-play, teachers witness a variety of approaches and then reflect as a group about what might work and what might not before attempting the activity with children. Thus, reflection and feedback are woven throughout the planning conversation as well as during the reflecting conversation.

**Data.** While observing teachers engage with children during lessons, coaches collected data using a form called “Teacher Interactions Tally Sheet” (see Appendix P). These data were
usually related to the specific “interactions” teachers chose to focus on during planning; tally marks count each time the teacher uses an interaction and quotes capture the teacher’s exact language. The form also contains space for coaches to “Describe an instance when the Big Ideas were well integrated into an interaction,” and “Describe a missed opportunity to integrate Big Ideas into an interaction.” The Collaborative Math Group Coaching Protocol clarifies the purpose: “With the addition of data to the conversation, we can help each teacher check her perceptions against evidence that was collected during the teaching episode.” Teacher 822 explains how data benefitted her practice: “We became more intentional and using the observation sheet helped us slow down and really be in tune with the children. The re-voicing was key for us.” The type of data to be collected are agreed upon in the planning conversation, and data are used to highlight the math content during the reflecting conversation:

After the observation, I like to begin by asking how the teacher felt it went and point out successful moments in which the children and/or teacher engaged with the big idea. Using the notes taken during the lesson, we then look at points during which the big idea could've been addressed differently during the lesson and then other things that can be done to build on some of those ideas. (Coach 22)

Additionally, the Collaborative Math website mentions video data. Documents specific to Collaborative Math do not set video collection as an expectation and it was mentioned by only one participant in the survey dataset, Teacher 733: “The benefit was she videotaped and we were able to see what we did.” It is unclear how often coaches may have used video as a data collection strategy during the current study.

**Questions and Direct Suggestions from Supportive Experts**

Within the literature, Cognitive Coaching involves the coach asking questions that prompt the teacher to reflect and come up with their own ideas, whereas Content-Focused Coaching involves the coach more often directly offering suggestions. Collaborative Math
presentations and protocols promote a Cognitive Coaching approach that focuses on asking questions, yet the coaching is linked to math content. Coaches and teachers describe both styles within the project, often commenting on the benefits and limitations of the approaches. One coach listed trainings on both Cognitive Coaching and Content-Focused Coaching as a way she had been supported in this work. Teachers think of the coaches as experts and discuss their role in promoting “accountability” to the project, suggesting a less balanced power dynamic than Knight’s Instructional Coaching literature about equal partnership.

**Questioning.** Teachers report that coaches asked questions and facilitated discussion. According to teacher 709: “[The coach’s] role is to ask questions. My role was to plan and reflect; hers was to probe me with questions to stimulate thinking, which she did.” Similarly, Teacher 863 said, “the coach asked thought provoking questions.” This use of questions to guide conversations is triangulated by coaches:

> I ask questions to get them to do the thinking and discovering and affirm how much they know as they do so. I keep the focus on the math and the students rather than on them and what they did or did not do. (Coach 24)

And in notes from consultations with instructional leaders:

> The coach always bring the discussion back to the Big Ideas and asks open ended questions like “tell me more” rather than telling the teachers what to think. (Instructional Leader Consultation Log, Center 105, Cycle 3)

Overall, coaches appear to strive toward asking questions as the ideal. For instance, Coach 25 describes a time that coaching was successful after a teacher was “resistant” explaining, “I asked lots of questions too, to get her to share her thoughts vs. me telling her what to do.” When asked about a time when coaching was not effective, Coach 24 said: “When I told a teacher directly what she needed to do. I felt rushed for time… Because of the time constraints of this project coaching was more directive than I would have liked.”
Teachers, in contrast, struggled with the question-heavy approach and were more likely than coaches and Collaborative Math materials to recall moments when coaches used a direct style.

The mode of communication was exhausting. I understand the use of thought provoking questions and having us realize things on our own, however it was a bit too much. I think there should be a combination of questions and conversation that are not so one sided. (Teacher 863)

I would suggest emailing reflective questions beforehand so that teachers can wrap their heads around discussion. Oftentimes during coaching meetings, I felt very...just drained, or unprepared for the questions that the coach was asking. I don't want to be groomed for certain answers, but maybe having some idea of what to be thinking about before those meetings would have been helpful. (Teacher 674)

These quotes reveal teachers feeling “exhausted” and “drained” from having to answer so many questions during coaching conversations. One teacher suggests that coaches should balance the questions with direct suggestions, and the other teachers proposes allowing more time to contemplate the questions.

**Direct Suggestions.** In survey responses, teachers recall instances and use language that suggest direct actions from their coach such as “showed” or “told” along with “feedback,” “offered suggestions” and “new ideas.” For example:

[T]he coach was there to support and show us a way that it could have been done differently offered suggestions on things we can improve on the next time we play the game or activity with the teacher. She showed us examples of the game and activity in a different way that can be used with children. (Teacher 988)

She showed my team and I how to help a child that was having trouble showing five using two hands. we learned how to put our fingers up to his fingers in order to help him show five using two hands. She showed us how to help them to move forward when playing great race game remember to say the number you get out loud. you spun a two you move two spaces. you was on one you spun a two now you are on three. (Teacher 496)
These quotes capture instances when teachers recall receiving support that was more directive than the question-focused style promoted by coaches and Collaborative Math documents. The two opposite coaching approaches may depend on a teacher’s personality and coaches may fluctuate between them within the same coaching session.

**Differentiation and Mixed Approaches.** Survey responses also highlight how coaches adapt their approach depending upon the needs of the teacher they are working with, as well as instances in which coaches may mix both questioning and direct suggestions within the same session or with the same teacher.

For example, Coach 20 explains that questioning works for teachers who are naturally more reflective, while others need more direct support:

> My coaching reflects the personality of the teachers. Some teachers are very reflective and only need to be asked questions while others need to have the questions combined with data or scripts from the observation. Also for some teachers, they will come up with their own ideas for developing their practice while others need some suggestions and even some practice in the reflection.

Thus, this coach modifies her approach to specific teachers. When describing coaching in the surveys, lead teachers more frequently report questioning compared to assistant teachers who more frequently report direct suggestions.

Teachers also comment about mixed approaches with a combination of both direct and questioning styles from their coach:

> I think my role was active at times with many things to say, other times I only listened, but the coach always asked questions to help us reflect on the activities. The coach always made the sessions interesting by facilitating discussions and helping us stay focus on the Math big ideas. (Teacher 681)

> I was always asked how I would prepare for an activity. The coach would fine tune my words and introductions to an activity. (Teacher 744)
We got to share our ideas and get positive feedback. We always plan in our unique way. (Teacher 700)

These quotes show that Collaborative Math’s approach is not singular and involves a balance of moments when teachers take initiative and moments with coaches take initiative.

**Coach as Supportive Expert.** Coaches view themselves and are viewed by teachers as math content experts who “push teachers” to “try new things with math” and “to keep the big ideas in mind.” Teachers compare the role of a coach to that of a teacher, with comments such as:

- She made me feel like I'm a student. (Teacher 860)
- The coach would give us an assignment… (Teacher 867)
- My coach was a reassuring teacher, she tried to ease my nervousness. (Teacher 828)
- My role is a learner and my coaches role is a supporter. (Teacher 404)
- I believe [the coach] taught wonderfully and helped us as much as they could understand the material. (Teacher 665)

Here, terms like “student,” “assignment,” “nervousness,” and “learner” suggest teachers view themselves as novices whereas terms like “reassuring,” “supporter,” “helped,” and “taught” suggest the teachers view their coaches as helpful experts. This expertise allows coaches to provide a unique perspective that teachers appreciate:

- A new set of eyes to help encourage and show the learning and teaching growth. (Teacher 954)
- A fresh pair of eyes to see what we were struggling with in doing the math activities. (Teacher 828)
- Our coach gave me suggestions and tips I would have never thought of. She would giving [sic] you ideas of how to word some thing to get the kids thinking. She would demonstrate revealing a different perspective or new insight. (Teacher 698)
The coach provided a different point of view and was able to give me advice that was very helpful. (Teacher 664)

We always had great feedback even when we thought we didn't do so great in a activity with the children our coach would show us and give us feedback on the things we did and it was great to see it from someone else's point of view. (Teacher 873)

These similar phrases including “new set of eyes,” “fresh pair of eyes,” “revealing a different perspective,” “provided a different point of view” and “see it from someone else’s point of view” capture a unique function of the coaches as a supportive outsider.

**Compliance with Compassion.** Responses also capture a sense of coaching for compliance and accountability, but with compassion. One teacher remarked that the role of the coach was to “make sure we knew what we was doing.” Several teachers comment about the coach helping correct “what we did wrong” during lessons, or express self-judgments such as “we didn't do so great” after the lesson. One teacher confessed:

I was nervous because I didn't want to play the games wrong during our planning and then I was nervous listening to the results of what I did wrong. My coach was a reassuring teacher, she tried to ease my nervousness. (Teacher 828)

Similar to the “reassuring teacher” characterization, the coaches are most commonly described as “helpful” (20 teachers used this term) or a “supporter” (seven teachers used this term). Teachers also use the terms “encouraging,” “professional,” “open,” “personable,” “available,” and “informative” to discuss their coaches. To prevent teachers from feeling judged, Coach 21 explained in her survey response that she “keep[s] the focus on the math and the students rather than on them and what [the teacher] did or did not do.”

**Group Format that Promotes Collaboration**

The Collaborative Math coaching model is also referred to as “Group Coaching” and “Collaborative Coaching.” Rather than one-on-one meetings between a coach and a single
teacher, which is the most common format in the literature reviewed for this study, coaches for this project met with multiple teachers at once. The group included one lead and one or two assistant teachers from the same classroom. Instructional leaders such as directors or curriculum specialist were also occasionally present.

The project is described as “center wide” with a goal of creating “centers of excellence in mathematics where quality early math instruction is fostered, celebrated, and sustained” (McCray et al., 2015). More specifically, one goal of the planning session listed in the coaching protocol is to “develop habits of collaborative planning.” Coaching logs also prompt coaches to ask teachers how they will support each other. Within the data, participants discuss including assistant teachers, learning from colleagues in other classrooms, and greater accountability as a result. They also mention limitations of the group coaching approach, including an inability to personalize and logistical challenges such as time and coverage.

“On the Same Page.” Both coaches and teachers mention how the group format allowed colleagues to get “on the same page for improving children’s math skills” (Teacher 458):

All the teachers in one site were hearing the same thing at one time and were working on the same learning together. They could celebrate their successes and safely discuss their challenges. (Coach 20)

I think the main goal of Collaborative Math coaching is to build within a school a common knowledge and understanding of how children develop foundational math concepts in order to support children's understanding of math, as well as to build their own confidence in their ability to support that understanding. (Coach 22)

The benefits were we all got the same information at the same time and that were able to communicate with each other in lesson planning. (Teacher 988)

It helped us recognize our strengths in partnering and how/when/where we could support each other in helping our children expand their math thinking. (Teacher 680)
Phrases such as “hearing the same thing at one time…working on the same learning together” and “build within a school a common knowledge and understanding” from coaches regarding their intent are confirmed in teachers’ responses about their experiences: “same information at the same time…were able to communicate with each other” and “recognize our strengths in partnering and how/when/where we could support each other.”

Overall, participants report that when all the adults working with children at a center participate in coaching, the staff develops common knowledge and is able to help each other. One way this occurs is within the classroom among lead and assistant teachers.

**Collaboration within Classrooms: Assistant Teachers.** Including assistant teachers in the full intervention is a unique feature of the Collaborative Math coaching model compared to most studies found within the reviewed literature. Among the 81 teachers in the treatment condition, 39 (48%) were lead teachers and 42 were assistant teachers (51.9%). Of these 42 assistants, 11 (13.6%) are a third teacher working in a classroom beside another assistant teacher and a lead teacher. Teachers recall examples of collaboration between teachers working together in the same classroom and how they believe this led to improved student learning:

I think the math program was a success because they trained all the teachers in the classroom. Teachers learned and implemented the same activities and we all worked together on planning and implementing of the activities. (Teacher 971)

It helps to make sure that we are on the same page and we can effectively help children in their math learning if we both have the knowledge and skills to engage them and build up their foundation in math. (Teacher 404)

These quotes from Teachers 971 and 404 express how common involvement allowed for shared lesson planning and implementation. Since content is a major focus, ensuring that all adults in the room share similar understanding of the math concepts avoids confusing students and allows
more opportunities for math learning which either teacher could lead. Another quote gives a specific example of what collaboration looks like in practice:

Coaching helped us both look out for skills in children while the other was presenting concepts, see who was catching on and those who needed more help. (Teacher 859)

In this classroom example, one teacher leads the lesson while the other uses her understanding to assess participating children in the moment, allowing children to benefit from the expertise of two adults at once.

At the same time, including assistant teachers also enhanced the professional identities of staff that often do not always receive opportunities for professional development:

The benefits included the opportunity [for] teacher assistants to participate and have a place at the table. Building their identity as adults who also facilitate learning. Hearing a variety of voices at the table flattened the hierarchy within each classroom team. Modeling the kinds of conversations about teaching and learning that need to occur among team members. The teams saw how this type of conversations impact the quality of instruction. Teachers supported each other. (Coach 24)

I felt that the coach helped me become more confident as a teacher 3 [assistant teacher], sometimes we feel that we don't make a difference but with this training I felt that we were all on the same page receiving the same training. (Teacher 450)

Overall, survey responses capture how including both lead and assistant teachers in coaching allows for common understanding which leads to enhanced lesson planning, increased opportunities for classroom adults to engage children in mathematical learning, and strengthened professional identities.

Collaboration across Classrooms. The emphasis on collaboration also allows teachers to support colleagues in other classrooms and compare understanding of the content and experiences with varying students:

With a team we can exchange ideas, we can support each other through doubts, and we learn from each other's experiences particularly with successes in different classrooms.
When on[e] team member has found something successful, we are able to translate that method into a different classroom. (Teacher 819)

One of the benefits was being able to listen to what works well and what doesn't work too well in other classrooms. It is always great to collaborate together and get ideas from one another. (Teacher 690)

The collaborative model also leaves room for differentiation to meet the unique needs of different classroom cultures, teaching styles, and students:

I think the benefit was that we were able to see each others interpretation of the learning labs and how we saw it playing out with our students in the classroom. (Teacher 859)

…we were all in the same page and we learned from each other. Although it was the same activity we all did it different. (Teacher 767)

As noted by Teacher 859, teachers learn the same information at Learning Labs and are then able to reflect together upon their understanding of the new content and how it applies to their particular children. This common base promotes discussion while still allowing for variation, as Teacher 767 noted.

**Center-Wide Accountability.** Involving all teachers together in a group format also results in greater accountability with teachers feeling more motivated to try new activities when they hear other teachers discuss them as well. This was explained by teachers:

I felt my role was important because sometimes my colleagues may not have remembered some of the concepts or understood the way I did and vice versa. Some people are more comfortable with math than others. Math has always been my favorite so I was excited about some the activities. (Teacher 698)

We gained accountability because we knew we were going to be observed so we really had to do the work and get the different activities going in our classroom. It was also nice to get feedback on what we were doing and have a chance to reflect on how well it went or what we could have done better. (Teacher 480)

and coaches as well:
everyone felt included as a team and could hear what each other was trying and how it was going - there was more accountability. Everyone heard and experienced the same information all together. (Coach 21)

The comments above demonstrate how the collaborative model allows for creation of shared knowledge, as well as group momentum to try new teaching strategies and persist through struggles with support from colleagues. Change is difficult and undergoing the process with others can make it less challenging and less lonely.

The benefit of being coached with my colleagues is that I was able to hear about the different students and struggles in other rooms. (Teacher 664)

The collaborative model may help teachers feel less alone and allow them to benefit from colleagues’ ideas when they encounter obstacles while attempting new teaching approaches or form new understanding of content.

I was comfortable to have my colleagues coaching me because they make me feel secure about my work. (Teacher 843)

To aid this process, coaching logs prompt for personalization by offering teachers individual choice and providing space for unique responses from each teacher. However, some participants still report lack of differentiation as a limitation of the group coaching model.

Differentiation Difficulties. When asked about benefits and limitations, many teachers directly state that there were “no limitations” to the group approach. When limitations did arise in the data, they were in reference to an inability to personalize coaching to the individual needs of teachers.

My colleagues and I are not on the same page when it comes to teaching so it was hard to just sit back and have to learn at their pace when I wanted to go further and do more. They also did not want to participate in the process so it made it less exciting for me to do all this stuff because I knew I would be the only one excited about doing it and the only one working on everything. (Teacher 480)
Teacher 480’s perspectives about differing learning paces and levels of engagement among her coaching group are echoed in Coach 21’s explanation of the challenges of helping quieter teachers in the same group coaching conversation as more vocal teachers who dominated conversation:

The limitations were that, during conversations, some teachers who were quieter or who felt less comfortable with math, could get lost in the cracks and avoid having to share because others who were more vocal were doing so. As a coach, I had to be mindful of asking the quieter teacher for her opinion from time to time. Also, at times there were dominant teachers who would take over the conversation and it was hard to manage because the others would just go along with this teacher and not really share what they were thinking… (Coach 21)

Symbolically, coaches also capture the challenges of differentiation in the way they fill out coaching logs. The forms are set up with three columns next to each question, designating a separate space for notes about each teacher’s response (see Appendix F). Instead of writing individual comments for each teacher, however, some coaches record as if all teachers in the group answered in unison. On handwritten logs coaches write ditto marks, or draw arrows from the first space across the other two, or ignore the dividing lines and write their responses across all three spaces. On typed logs, coaches copy and paste the exact same text for each teacher as if all three teachers gave the exact same response.

Furthermore, teachers and coaches discuss how group dynamics can lead to performance anxiety that may not occur during one-on-one coaching:

I did not want to be judged by my colleagues for my questions. (Teacher 649)

Sometime with my colleagues I felt like if my children were not at the level [of] their children they would look down on me, like what are you not doing with your children. (Teacher 555)

For some of my peers, I felt they were a bit shy in the group coaching. (Teacher 645)

It became awkward if you needed to address a specific issue. (Coach 20)
Thus, coaches must attune to differences in content knowledge, confidence, and teaching practice as well as personalities and interest in the intervention.

RQ1b. What are the Qualifications and Demographics of Collaborative Math Coaches?

A total of eight coaches were part of the Collaborative Math intervention during the 2016-2017 academic year. Two of the senior coaches are employed full time, work on the Content Development Team with other Early Math Collaborative staff, and act as supervisors overseeing all coaches. The other coaches work part time with hours that vary year to year based upon need, and may serve on multiple projects at once. Five coaches from the Collaborative Math project in 2016-2017 responded to this survey.

Education

All coaches employed by the Early Math Collaborative have a master’s degree. In this sample, coaches listed the following degrees:

- BA in Communications, MAT in Early Childhood
- BA in Early Childhood and Literacy, MS in Special Education
- BS in Early Childhood Education, MS in Early Childhood Education w/ Teacher Certification
- BA in Elementary Education, MS in Early Childhood Education
- BA in Political Science, MA in Education

Four coaches report holding a Professional Educator License; three coaches with an early childhood endorsement (birth – grade 3) and one coach with an elementary endorsement (kindergarten – grade 9). Three coaches have Bilingual/ELL endorsements, and one coach has a Special Education endorsement.
Classroom Teaching Experience

All coaches employed by the Early Math Collaborative are former classroom teachers. In this sample, coaches reported experience working directly with children as a classroom teacher for an average of 10 years (range 4-15). All coach respondents have taught in elementary settings; one coach also taught preschool, another coach also taught middle school, and another coach also taught preschool and toddlers. This last coach was also the only one with prior experience teaching in Head Start settings.

Coaching Experience

On average, coaches were employed with the Early Math Collaborative for 9.5 years (ranging from eight years and six months to 11 years). Two coaches had no prior experience as a coach before joining the Early Math Collaborative; one coach reported four years prior experience as a coach, another reported 17 years, and one coach did not respond to this question. Of the four coaches who responded to this question, all had experience coaching in Head Start settings, childcare centers, and elementary schools before coaching as part of Collaborative Math. Two coaches also had experience in family childcare settings.

Coaching Support

All coaches report growth when asked to rate (a) their math content knowledge; (b) their ability to teach preschool math; (c) their math confidence; and (d) their skill as a coach before they began working with the Early Math Collaborative compared to now. Coaches report being supported in their work through:

- formal supervision meetings with senior staff
- group discussions with other coaches
- a culture of collaboration and open communication
• resources such as articles and books

• external professional development such as attending conferences or workshops focused on math or coaching.

In the words of one coach:

EMC has supported my work by helping me see myself as a mathematician. There is always someone around to ask questions, if necessary, but it has really been in through engaging in mathematical thinking that my confidence and ability to support others has grown and therefore supported my work as an early math coach. (Anonymous Coach)

Early Math Collaborative coaches are required to attend one Coach Meeting each month August through May. Agendas show meetings are three hours long and begin with time for coaches to engage in adult-level math play. Agenda topics include communicating logistics, sharing individual coach’s successes and troubleshooting challenges, reviewing resources such as articles, and role-playing to practice coach moves. Coaches co-facilitate Learning Labs alongside senior Early Math Collaborative staff on the Content Development Team, and prepare by attending a “Talk-Thru Meeting” to review outlines as a group and meet one-on-one with their co-facilitator. Coaches also attend Leadership Academics led by the two Coach Supervisors in a hybrid role, sitting alongside Instructional Leaders from their Head Start sites to deepen their own understanding of math and coaching while also leading discussions with participants at their tables.

**Identities**

All participating coaches identify as female. To report race/ethnicity, three coaches selected just Hispanic/Latino, one selected just White/Caucasian, and one selected both Hispanic/Latino and White/Caucasian.
Languages

All five participating coaches self-reported fluency in Spanish, with four reporting English as their primary language and one reporting Spanish as their primary language. All surveys were conducted in English.

Summary of Research Question 1: Coaching Model and Coaches

In summary, Collaborative Math’s coaching model is characterized by the terms “collaborative,” “group,” “content-focused,” “cognitive,” and “instructional.” Coaching involves planning, enacting, and reflecting upon common “research lessons” that focus on select math concepts known as “big ideas.” Planning emerged as the most salient component across data sources. During planning conversations, teachers engage in role-play to practice pedagogical choices known as “teaching interactions” and rehearse the language they will use with children. Coaches collect data during the lesson to guide the reflecting conversation. Throughout conversations, coaches employ a mix of asking questions and offering direct suggestions. Comments from coaches suggest that they believe questioning is the ideal whereas teachers discuss the usefulness of direct suggestions.

Commonly, teachers view coaches as supportive experts who promote compliance to the intervention with compassion. Coaching occurs in a group format that allows colleagues to get “on the same page” regarding math content knowledge and teaching strategies. Group coaching also promotes collaboration within classrooms between lead and assistant teachers, as well as collaboration across classrooms with other teachers at the same site, which all leads to center-wide momentum. Participants report performance anxiety and lack of personalization as potential limitations to the group approach. All coaches have teaching-related master’s degrees and identify as female. On average, coaches possess 10 years classroom teaching experience and 9.5
years coaching experience. The majority of coaches identify as Hispanic/Latino and are fluent in English and Spanish. Finally, coaches are supported around math content and coaching techniques through formal meetings, printed resources, and a culture of open communication.

**Research Question 2: What is the Unique Contribution of Coaching among Other Intervention Inputs?**

**RQ2a. After Accounting for Pre-Test Scores, Learning Lab Attendance, and Teacher Demographics, Do Varying Amounts of Coaching Predict Shifts in Knowledge, Practice, and/or Dispositions?**

This section first describes each variable before reporting on the results from quantitative analysis for each of the three guiding sub questions. Dependent variables include spring outcome scores for EQUIP-M (practice), ABC-PM (dispositions), and PM-PCK (knowledge). Independent variables include coaching amount, coach, learning lab attendance, teacher’s role, instructional leader involvement, and baseline scores for each measure.

**Dependent Variables: Teacher Outcome Measures**

An overview of the pooled means and standard deviations of the outcome variables by intervention condition are provided in Table 9.
Table 9. Pooled Means and Standard Deviation of Outcomes by Intervention Condition

<table>
<thead>
<tr>
<th>Outcome Measure</th>
<th>Intervention N = 72</th>
<th></th>
<th></th>
<th></th>
<th>Comparison N = 69</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Min</td>
<td>Max</td>
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<td>SD</td>
<td>Min</td>
<td>Max</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>EQUIP-M Baseline</td>
<td>6.69</td>
<td>21.00</td>
<td>13.65</td>
<td>2.67</td>
<td>6.27</td>
<td>21.77</td>
<td>13.22</td>
<td>2.45</td>
</tr>
<tr>
<td>EQUIP-M Spring</td>
<td>6.37</td>
<td>23.71</td>
<td>14.61</td>
<td>2.59</td>
<td>4.65</td>
<td>21.50</td>
<td>13.83</td>
<td>2.82</td>
</tr>
<tr>
<td>Attitudes Baseline</td>
<td>1.10</td>
<td>5.00</td>
<td>3.03</td>
<td>.63</td>
<td>1.4</td>
<td>4.9</td>
<td>3.07</td>
<td>.72</td>
</tr>
<tr>
<td>Attitudes Spring</td>
<td>1.00</td>
<td>5.00</td>
<td>3.16</td>
<td>.66</td>
<td>1.02</td>
<td>5.00</td>
<td>3.14</td>
<td>.79</td>
</tr>
<tr>
<td>Confidence Baseline</td>
<td>2.01</td>
<td>4.69</td>
<td>3.37</td>
<td>.44</td>
<td>2.00</td>
<td>4.59</td>
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<tr>
<td>Confidence Spring</td>
<td>2.39</td>
<td>4.91</td>
<td>3.72</td>
<td>.37</td>
<td>2.27</td>
<td>4.76</td>
<td>3.56</td>
<td>.49</td>
</tr>
</tbody>
</table>

**Teachers Practice: EQUIP-M**

Median EQUIP-M scores were chosen as the variable to capture teachers’ practice at baseline and again in spring. Per the tool’s design, each teacher was videotaped on three separate occasions per time point, and each of these videos were then scored by a trained team of experts and teachers for a maximum of 32 possible points. Mean and median scores were similar with an average difference of 0.04 points (ranging at most from -3.33 to +3.00 points). By using the median score rather than the mean score, a teacher’s unusually bad day does not artificially lower their score, nor does an unusually good lesson artificially inflate it. When a teacher had missing data for one of the three videos the average of their two scores was substituted for the median.

Among participants in the intervention condition (n = 72), the mean score at baseline was 13.65, ranging from 6.69 to 21.00 (SD = 2.67). In spring, the mean score for intervention condition participants was 14.61, ranging from 6.37 to 23.71 (SD = 2.69). For the comparison condition (n = 69), the mean score at baseline was 13.22, ranging from 6.27 to 21.77 (SD =
2.45). And in spring, the mean score for intervention condition participants was 13.83, ranging from 4.65 to 21.50 (SD = 2.82).

**Teacher Dispositions: ABC-PM**

Using a 5-point Likert scale (1 = Strongly Disagree; 5 = Strongly Agree) teachers responded to questions related to their math attitudes, beliefs, and confidence. Mean scores for attitudes and confidence were used for analysis; mean scores were chosen over total scores to retain a sense of scale for interpretation.

**Attitudes.** Among participants in the intervention condition (n = 72), the mean score at baseline was 3.03, ranging from 1.10 to 5.00 (SD = 0.63). In spring, the mean score for intervention condition participants was 3.14, ranging from 1.11 to 5.00 (SD = 0.66). For the comparison condition (n = 69), the mean score at baseline was 3.07, ranging from 1.40 to 4.90 (SD = 2.72). And in spring, the mean score for intervention condition participants was 3.16, ranging from 1.02 to 5.00 (SD =0.79).

**Beliefs.** Using exploratory factor analysis, Collaborative Math researchers found the tool was not effective at capturing teachers’ beliefs about math during the pilot study (Quest et al., 2016) so questions regarding this aspect were omitted from the survey administered to participants. This is triangulated by limited findings related to beliefs in the qualitative data. Therefore, beliefs were not examined as an aspect of teachers’ dispositions.

**Confidence.** Among participants in the intervention condition (n = 72), the mean score at baseline was 3.37, ranging from 2.01 to 4.69 (SD = 0.44). In spring, the mean score for intervention condition participants was 3.72, ranging from 2.39 to 4.91 (SD = 0.37). For the comparison condition (n = 69), the mean score at baseline was 3.28, ranging from 2.00 to 4.49
(SD = 0.48). And in spring, the mean score for intervention condition participants was 3.56, ranging from 2.27 to 4.76 (SD = 0.49).

**Teacher Knowledge: PM-PCK**

Data for PM-PCK required to determine teachers’ knowledge is unavailable due to complications with the tool’s scoring system, which is currently undergoing revision by Collaborative Math researchers. This will be addressed in the discussion in Chapter 5.

**Independent Variables**

**Coaching Dosage**

Teacher attendance and conversation length in minutes were both reported by coaches in Fidelity Surveys after each of the five coaching cycles. The amount of coaching that participants in the intervention condition received was explored in three ways: (a) the total number of Group Coaching conversations and lessons that a teacher attended; (b) the amount of coaching time broken down by type: planning conversation, lesson observation, and reflecting conversation; and (c) the total amount of time a teacher spent in Group Coaching. Table 10 provides a summary of the amount of coaching. Note that the total amount of coaching was obtained by first summing the three meeting types for individual participants and then using each participant’s individual total to run descriptive analysis. Thus, adding together the minimum, maximum, and mean for planning, lesson, and reflecting does not equal the minimum, maximum, or mean for total amount of coaching. For example, a teacher might have the lowest amount of planning time compared to other participants but not the lowest amount of lesson time and reflecting time. Therefore, the minimum total amount of coaching is equal to or greater than each meeting type, and the maximum total amount of coaching is equal to or less than each meeting type.
Table 10. Coaching Dosage across All 5 Cycles of the Intervention (n = 72)

<table>
<thead>
<tr>
<th></th>
<th>Number of Meetings</th>
<th>Minutes</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Minimum</td>
<td>Maximum</td>
</tr>
<tr>
<td>Planning</td>
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</tr>
<tr>
<td>Lesson</td>
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<td>5</td>
</tr>
<tr>
<td>Reflecting</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Total</td>
<td>3</td>
<td>15</td>
</tr>
</tbody>
</table>

**Number of Meetings and Cycles.** On average, participants attended 13 of the 15 meetings (13.57, SD = 3.437). Attendance was highest for reflecting (4.24, SD = 1.179), followed by planning (4.18, SD = 1.179) and lessons (4.15, SD = 1.252).

**Time Spent in Group Coaching.** Across the five coaching cycles from October to April, teachers spent an average of 499 minutes (about 8.25 hours) with their coach, with classroom group coaching totals ranging from 130 minutes (about 2.15 hours) to 755 minutes (about 12.5 hours).

The most time was spent in planning conversations. In a single cycle, teachers and coaches reportedly planned for 10 to 90 minutes, and planning conversations lasted 45 minutes on average. In total across all 5 cycles, teachers participated in an average total of 196 minutes (about 3.25 hours) planning with their coach, ranging from 40 minutes to 281 minutes (about 4.75 hours).

Reflecting conversations ranged from 10-75 minutes long, with an average of 42 minutes per cycle. Across all five cycles, teachers spent an average total of 185 minutes (about three hours) in reflecting conversations, ranging from 30 minutes to 300 minutes (about five hours).

The least amount of coaching time was spent during the lessons, reportedly ranging from 2-70 minutes and averaging 27 minutes per cycle. Across all five cycles, teachers spent an average total of 118 minutes (about two hours) leading lessons while their coach was present,
ranging from 30 minutes to 215 minutes (about 3.5 hours). If another teacher was also present, but was not the main facilitator of the lesson and thus not the main focus of their coach, this is not counted toward their totals.

**Coach**

There were eight coaches. The number of participants in the final sample assigned to the same coach ranged from 3-20, with an average of 9 teachers per coach. Coaches worked with 1-4 centers, and all teachers in the same center worked with the same coach. Since nominal variables cannot be used in regression, coach was converted to dummy variables by designating a reference category and creating seven new variables. A value of 1 was assigned to every participant who worked with that coach and 0 for every participant who did not.

**Teacher Role**

Teachers were classified as either lead (1) or assistant (0). In the intervention sample, 31 participants were lead teachers and 33 participants were assistant teachers. In the comparison sample, 32 participants were lead teachers and 37 participants were assistant teachers.

**Learning Lab Attendance.** Of the 6 possible Learning Labs, attendance in the intervention condition ranged from 3-6 labs with an average of 5.81 (SD = 0.547). Since Learning Lab attendance was high and is not normally distributed, it was excluded from analyses.

**Instructional Leader Support.** To represent the varying levels of involvement for instructional leaders across the intervention, a composite score was calculated by adding together: the total number of Learning Labs attended (0-6); the total number of Leadership Academies attended (0-6); the total number of Group Coaching Sessions the leader was present during (0-56); the total number of times the leader was present during all three pieces of Group
Coaching—the planning, lesson, and reflecting-- with the same classroom within a single cycle (0-18); the total number of times the leader was present at all three pieces of Group Coaching but not consistently with the same classroom (0-18); the total number of Instructional Leader Consultation sessions attended (0-20); and the total number of full cycles where the leader attended all required consultations (0-6). If two Instructional Leaders who work together at the same center were both involved, as was the case for half of the centers, their totals were combined and then divided by 2. Final scores ranged from 15 to 52, with an average of 29.35 points (SD = 0.547).

**Analytic Results**

*Were Intervention and Comparison Groups Similar at Baseline?*

Three independent-samples t-tests were run to establish that cohorts did not differ at baseline.

**Practice at Baseline.** There were no outliers in the data, as assessed by inspection of a boxplot. EQUIP-M scores for each cohort were normally distributed, as assessed by Shapiro-Wilk's test ($p > .05$) and visual inspection of a Q-Q plot. There was homogeneity of variances, as assessed by Levene's test for equality of variance ($p = 0.68$). Participant’s mean scores for the intervention group were slightly higher ($M = 13.66$, $SD = 2.7$) than the comparison group ($M = 13.64$, $SD = 0.34$) but this was not a statically significant difference $t(139) = 0.921$, $p = 0.357$. Therefore, there were no differences between intervention and comparison groups for in teachers’ practice at baseline.

**Attitudes at Baseline.** Two outliers were detected that were more than 1.5 box-lengths from the edge of the box in a boxplot. Analysis was run with and without outliers; outliers were retained since results did not differ sufficiently. Attitude scores for each cohort were normally
distributed, as assessed by Shapiro-Wilk's test \( p > .05 \) and visual inspection of a Q-Q plot.

There was homogeneity of variances, as assessed by Levene's test for equality of variance \( (p = 0.289) \). Participants’ mean scores for the comparison group \( (M = 3.07, SD = 0.78) \) were slightly higher compared to the intervention group \( (M = 3.02, SD = 0.86) \) but the difference was not statically significant \( t(139) = -0.402, p = 0.687 \). Therefore, there were no differences in teachers’ math attitudes between intervention and comparison groups at baseline.

**Confidence at Baseline.** There were four outliers, as determined by inspection of a boxplot. Analysis was run with and without outliers; outliers were retained since results did not differ sufficiently. There was homogeneity of variances, as assessed by Levene's test for equality of variance \( (p = 0.476) \). Participants’ mean scores for the comparison group \( (M = 3.27, SD = 0.55) \) were very close to the intervention group \( (M = 3.28, SD = 0.57) \) and the difference was not statically significant \( t(139) = -0.118, p = 0.906 \). Therefore, there were no differences in teachers’ math confidence between intervention and comparison groups at baseline.

**Did the Overall Intervention Shift Teachers’ Outcome Scores?**

A linear mixed model (HLM) was run with all participants \( (n = 141) \) to determine if study condition was a significant predictor of spring outcome scores after controlling for baseline scores and center.

**Assumptions.** There was a linear relationship between spring and baseline confidence scores for each study condition cohort, as assessed by visual inspection of a scatterplot. There was no multicollinearity, as assessed by tolerance levels greater than 0.1. There was homogeneity of variances, as assessed by Levene's test \( (p > .05) \). Standardized residuals for the interventions were normally distributed, as assessed by Shapiro-Wilk's test \( (p > .05) \) and visual inspection of Q-Q plots.
**Intraclass Correlation Coefficients.** The ICC is 0.14035 for EQUIP-M, 0.01065 for attitudes, and 0.00027 for confidence. This means the center at which a teacher works explains 14% of the variance for their practice, whereas the center only explains 1% of their attitude toward math teaching and 0% of their confidence in math teaching.

**Overall Shifts in Practice.** Participants’ EQUIP-M median scores were greater in the intervention group (M = 14.61, SD = 2.59 points) compared to the comparison group (M = 13.83, SD = 2.82 points). After adjusting for center clustering and teachers’ baseline EQUIP-M median scores, there was not a statistically significant difference in post-intervention EQUIP-M scores between the intervention and comparison, $\beta = 0.875$, $t(15) = 1.429$, $p = 0.153$.

**Overall Shifts in Attitudes.** Participants’ spring ABC-PM Attitude scores were greater in the intervention group (M = 3.16, SD = 0.66 points) compared to the comparison group (M = 3.15, SD = 0.79 points). After adjusting for center clustering and teachers’ baseline, this difference was not statistically significant $\beta = 0.189$, $t(15) = 0.436$, $p = 0.663$.

**Overall Shifts in Confidence.** Participants’ spring ABC-PM Confidence scores were greater in the intervention group (M = 3.72, SD = 0.37 points) compared to the comparison group (3.53, SD = 0.49 points). Estimates of fixed effects could not be computed because “the Hessian Matrix is not positive definite” (see West et al., 2007 for a detailed explanation). This occurred because the ICC is zero and center cluster does not impact confidence scores. Therefore, center cluster was removed and an ANCOVA was run instead with spring confidence scores as the dependent variable, study condition as the independent variable, and baseline confidence scores as the covariate. After adjusting for baseline confidence scores, there was a statistically significant difference between the intervention and comparison groups, $F(1, 138) = 5.687$, $p = 0.018$. 
Does Coaching Dosage Impact Teacher Outcomes?

A linear mixed model (HLM) was run with intervention participant data (n = 72) to determine if total time in each coaching meeting type (planning, lesson, observation) was a significant predictor of spring outcome scores after controlling for baseline scores, assigned coach, instructional leader involvement, and teacher’s role.

**Intraclass Correlation Coefficients.** For the intervention participant sample, the ICC is 0.107 for EQUIP-M, 0.0804 for attitudes, and 0.00012 for confidence. This means the center at which a teacher works explains 11% of the variance for their practice and 8% of the variance for their attitude toward math teaching, and none of their confidence in math teaching.

**Coaching Dosage and Teaching Practice.** The amount of time spent in planning, lesson, or reflecting conversations was not a significant predictor of EQUIP-M scores according to the HLM model both before and after controlling for center clustering, instructional leader (IL) involvement, assigned coach, and baseline scores. Pooled estimates of fixed effects for the full model are displayed in Table 11.

Table 11. Pooled Estimates of Fixed Effects for EQUIP-M (Practice)

<table>
<thead>
<tr>
<th>Model</th>
<th>B</th>
<th>SE</th>
<th>t</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning Time</td>
<td>.0125</td>
<td>.00781</td>
<td>1.606</td>
<td>.108</td>
</tr>
<tr>
<td>Lesson Time</td>
<td>-.0148</td>
<td>.0103</td>
<td>-1.442.108</td>
<td>.150</td>
</tr>
<tr>
<td>Reflecting Time</td>
<td>-.0004</td>
<td>.0102</td>
<td>-.042</td>
<td>.966</td>
</tr>
<tr>
<td>IL Involvement</td>
<td>-.0390</td>
<td>.0492</td>
<td>-.793</td>
<td>.428</td>
</tr>
<tr>
<td>Teacher’s Role</td>
<td>-.1919</td>
<td>.6485</td>
<td>-.296</td>
<td>.767</td>
</tr>
<tr>
<td>Baseline EQUIP-M</td>
<td>.2777</td>
<td>.1517</td>
<td>1.830</td>
<td>.068</td>
</tr>
<tr>
<td>Coach 92</td>
<td>2.8466</td>
<td>2.5852</td>
<td>1.101</td>
<td>.271</td>
</tr>
<tr>
<td>Coach 93</td>
<td>1.1412</td>
<td>1.852</td>
<td>.762</td>
<td>.446</td>
</tr>
<tr>
<td>Coach 94</td>
<td>1.673</td>
<td>1.807</td>
<td>.926</td>
<td>.355</td>
</tr>
<tr>
<td>Coach 95</td>
<td>2.187</td>
<td>1.912</td>
<td>1.115</td>
<td>.265</td>
</tr>
<tr>
<td>Coach 96</td>
<td>3.283</td>
<td>1.935</td>
<td>1.696.</td>
<td>.090</td>
</tr>
<tr>
<td>Coach 97</td>
<td>1.343</td>
<td>1.3431</td>
<td>558</td>
<td>.577</td>
</tr>
<tr>
<td>Coach 98</td>
<td>-.0316</td>
<td>-.0316</td>
<td>-.019</td>
<td>.985</td>
</tr>
</tbody>
</table>
Coaching Dosage and Teachers’ Attitudes about Math Teaching. The amount of time spent in planning, lesson, or reflecting conversations was not a significant predictor of Attitude scores according to the HLM model both before and after controlling for center clustering, instructional leader (IL) involvement, assigned coach, and baseline scores. Only baseline Attitude scores were a significant predictor of spring Attitude scores, \( p < .05 \). Pooled estimates of fixed effects for the full model can be found in Table 12.

Table 12. Pooled Estimates of Fixed Effects for Attitudes

<table>
<thead>
<tr>
<th>Model</th>
<th>B</th>
<th>SE</th>
<th>( t )</th>
<th>( p )-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning Time</td>
<td>-.0006</td>
<td>.0014</td>
<td>-.437</td>
<td>.662</td>
</tr>
<tr>
<td>Lesson Time</td>
<td>-.0022</td>
<td>.0016</td>
<td>-.1391</td>
<td>.164</td>
</tr>
<tr>
<td>Reflecting Time</td>
<td>.0013</td>
<td>.0017</td>
<td>.803</td>
<td>.422</td>
</tr>
<tr>
<td>IL Involvement</td>
<td>-.0057</td>
<td>.1029</td>
<td>-.446</td>
<td>.656</td>
</tr>
<tr>
<td>Teacher’s Role</td>
<td>.0812</td>
<td>.1069</td>
<td>.759</td>
<td>.448</td>
</tr>
<tr>
<td>Baseline Attitude</td>
<td>.8235</td>
<td>.0983</td>
<td>8.375</td>
<td>.000</td>
</tr>
<tr>
<td>Coach 92</td>
<td>-.4246</td>
<td>.6947</td>
<td>-.611</td>
<td>.541</td>
</tr>
<tr>
<td>Coach 93</td>
<td>-.4591</td>
<td>.4994</td>
<td>-.919</td>
<td>.358</td>
</tr>
<tr>
<td>Coach 94</td>
<td>-.2169</td>
<td>.4939</td>
<td>-.440</td>
<td>.660</td>
</tr>
<tr>
<td>Coach 95</td>
<td>-.4040</td>
<td>.5553</td>
<td>-.727</td>
<td>.467</td>
</tr>
<tr>
<td>Coach 96</td>
<td>.2156</td>
<td>.5249</td>
<td>.411</td>
<td>.681</td>
</tr>
<tr>
<td>Coach 97</td>
<td>-.1265</td>
<td>.5757</td>
<td>1.220</td>
<td>.826</td>
</tr>
<tr>
<td>Coach 98</td>
<td>-.0898</td>
<td>.4657</td>
<td>-.193</td>
<td>.847</td>
</tr>
</tbody>
</table>

Coaching Dosage and Teachers’ Confidence in Teaching Math. Due to the ICC of 0, a multiple regression was run instead of HLM to predict teachers’ confidence scores from planning time, lesson time, reflecting time, teacher role, assigned coach, instructional leader (IL) involvement, and baseline confidence scores.

There was linearity as assessed by partial regression plots and a plot of studentized residuals against the predicted values. There was independence of residuals, as assessed by a Durbin-Watson statistic of 2.067. There was homoscedasticity, as assessed by visual inspection
of a plot of studentized residuals versus unstandardized predicted values. There was no evidence of multicollinearity, as assessed by tolerance values greater than 0.1. There were no studentized deleted residuals greater than ±3 standard deviations and no values for Cook's distance above 1. The assumption of normality was met, as assessed by a Q-Q Plot.

The multiple regression model statistically did not significantly predict teachers’ confidence scores, \( F(13, 58) = 1.284, p = 0.249 \). R-squared for the overall model was 0.224, a small effect size according to Cohen (1988). Only baseline confidence scores added statistical significance to the prediction, \( p < .05 \). Pooled regression coefficients and standard errors can be found in Table 13.

Table 13. Pooled Multiple Regression Results for Confidence

<table>
<thead>
<tr>
<th>Model</th>
<th>B</th>
<th>SE</th>
<th>t</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning Time</td>
<td>.001</td>
<td>.001</td>
<td>.920</td>
<td>.358</td>
</tr>
<tr>
<td>Lesson Time</td>
<td>.000</td>
<td>.001</td>
<td>.241</td>
<td>.810</td>
</tr>
<tr>
<td>Reflecting Time</td>
<td>-.001</td>
<td>.002</td>
<td>-.374</td>
<td>.708</td>
</tr>
<tr>
<td>IL Involvement</td>
<td>-.002</td>
<td>.006</td>
<td>-.316</td>
<td>.752</td>
</tr>
<tr>
<td>Teacher’s Role</td>
<td>.044</td>
<td>.104</td>
<td>.423</td>
<td>.673</td>
</tr>
<tr>
<td>Baseline Confidence</td>
<td>.293</td>
<td>.116</td>
<td>2.521</td>
<td>.012</td>
</tr>
<tr>
<td>Coach 92</td>
<td>.234</td>
<td>.331</td>
<td>.706</td>
<td>.481</td>
</tr>
<tr>
<td>Coach 93</td>
<td>.064</td>
<td>.245</td>
<td>.262</td>
<td>.793</td>
</tr>
<tr>
<td>Coach 94</td>
<td>.027</td>
<td>.232</td>
<td>.116</td>
<td>.908</td>
</tr>
<tr>
<td>Coach 95</td>
<td>.026</td>
<td>.238</td>
<td>.110</td>
<td>.913</td>
</tr>
<tr>
<td>Coach 96</td>
<td>.141</td>
<td>.268</td>
<td>.528</td>
<td>.598</td>
</tr>
<tr>
<td>Coach 97</td>
<td>-.267</td>
<td>.286</td>
<td>-9.36</td>
<td>.350</td>
</tr>
<tr>
<td>Coach 98</td>
<td>.062</td>
<td>.219</td>
<td>-3.74</td>
<td>.776</td>
</tr>
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</table>

Summary of Research Question 2a: Impact of Coaching on Teacher Knowledge, Practice, and Dispositions

In total across the five coaching cycles, teachers in the intervention condition spent an average of 499 minutes (about 8.25 hours) with their coach. The most time was spent planning (196 minutes or about 3.25 hours), followed by reflecting (185 minutes or about 3 hours), and
then lessons (118 minutes or about two hours). Learning Lab attendance was high, so this variable was excluded from analysis. A composite score was calculated to represent the level of instructional leader participation for an average of 29.35 points, which ranged from 15 to 52. Coaches worked with an average of nine teachers, ranging from 3-20 teachers, at 1-4 centers.

T-tests determined that the intervention and comparison groups were similar at baseline for all three measures. The intraclass correlation of 0.14035 for EQUIP-M (practice), 0.01065 for attitudes, and 0.00027 for confidence means that the center at which a teacher works has a 14% influence on their practice and 1% influence on their attitudes. Therefore, HLM was used for these measures to account for center clustering within the model. The center at which a teacher works has 0% influence on a teachers’ confidence score, so ANCOVA was used for this measure. After adjusting for baseline confidence scores, there was a statistically significant difference between the intervention and comparison groups, $F(1, 138) = 5.687, p = .018$. Intervention condition was not a significant predictor of attitude or EQUIP-M (practice) scores. The amount of time spent in planning, lesson, or reflecting conversations was not a significant predictor of teacher outcomes for practice, attitudes, or confidence. The teacher’s role (lead or assistant), the particular coach assigned to a center, and the level of instructional leader involvement were also not significant predictors of outcomes.

RQ2b: How Do Coaches and Teachers Describe Shifts in Knowledge, Practice, and/or Dispositions in Relation to Coaching? What Other Coaching Related Outcomes Do They Mention?

To complement the quantitative results from RQ2a, an additional analysis of qualitative data sought to uncover participants’ perceptions of shifts through examples from both coaches and teachers that give insight into the process of teacher change and how specific aspects of
coaching might contribute. “Shifts” refer to areas with potential for change, including both challenges ripe for intervention and perceived evidence of impact. In addition to coach and teacher surveys, the data analyzed for Research Question 2b included a subsample of logs filled out by coaches during planning and reflecting conversations.

After applying *a priori* codes and subcodes from the Whole Teacher Approach (Chen & McCray, 2012), frequency counts show 168 code applications for shifts in *knowledge* compared to 108 code applications for shifts in *practice* and 66 code applications for shifts in *dispositions*. Descriptions of shifts in knowledge are also richer than the other two areas. Using language directly from the Whole Teacher Approach, shifts in knowledge include *how to teach math* (awareness of effective instructional methods), *what to teach* (important math content), and *who is taught* (knowledge of child development). Shifts in practice include *implementing new strategies*, *addressing weak spots*, and *persisting in incorporation of new ideas*. Shifts in teachers’ dispositions include *confidence in their ability to teach math* and a *belief that math is important* enough to be incorporated across the curriculum and shared with families. Two frequently mentioned specific examples will be used to illustrate how these shifts operate together: the “teacher interaction” called “say what you see” and the pedagogical practice of encouraging children to “subitize” or recognize small quantities quickly without counting. Finally, increased collaboration and shifts in relationships among colleagues are additional coaching-related outcomes that emerged from the data.

**Shifts in Knowledge**

Shifts in knowledge include understanding of what to teach, how to teach it, and who is taught.
Knowledge of WHAT to Teach (Content Knowledge). As discussed above, understanding math content is a major goal of the Collaborative Math intervention. Therefore, it follows that teachers’ comprehension of important math concepts for young children is a main source of shifts captured in Group Coaching logs and also described in surveys. There is a shift toward an overall greater emphasis on math, as well as evidence of teachers moving from confusion about math concepts to being able to explain them thoroughly.

Each coaching cycle focused on 1-3 “big ideas,” (often abbreviated in logs as “BIs”) and the first prompt on coaching forms asks teachers to recall this content from Learning Labs:

What did the teachers identify as the Big Ideas we want children to have a chance to wrestle with during this activity? Did the teachers use the [Big Ideas in Early Math] book or did they remember it on their own? - Group Coaching: Planning Conversation form

Next to this prompt, coaches jot notes regarding teachers’ confusion about the math concepts, such as “difficult for them to articulate, not always conscious of BIs” (Center 100, Cycle 1) and “needed help to ID big ideas of activity (Center 101, Cycle 4).”

An excerpt from the Planning Log for Center 105, Cycle 3 (see Figure 9) demonstrates partial understanding that the coach helped clarify:

<table>
<thead>
<tr>
<th>Preparing to Conduct Activity</th>
<th>T1: 521</th>
<th>T2: 591</th>
<th>T3: 520</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>What did the teachers identify as the Big Ideas we want children to have a chance to wrestle with during this activity? Did teachers use the book or did they remember it on their own?</strong></td>
<td>Remembered the word subitizing but not the meaning.</td>
<td>Remembered subitizing without support – and the definition.</td>
<td>Needed book and coach support</td>
</tr>
<tr>
<td><strong>Needed book. Coach discussed the 2nd big idea – quantity as an attribute.</strong></td>
<td>Coach discussed the 2nd big idea – quantity as an attribute.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 9. Excerpt from Planning Log, Center 105, Cycle 3

In this example, teacher 510 required support from her book and coach to identify the “big ideas” that are the target of the lesson. Teacher 521 remembered the word “subitizing” but
not the meaning. Teacher 591 was able to define the term, but needed support to remember the related “big idea” that quantity is an attribute.

In an additional example from Center 101, Cycle 5 (see Figure 10) a coach reports teachers’ full understanding: “[Instructional leader] asked about [big ideas] + both [teachers] were able to discuss the number relationships the game highlighted [:] magnitude, stable order, Subitizing, 1-1, 1 more/2 more, cardinality.”

![Figure 10. Excerpt from Planning Log, Center 101, Cycle 5](image)

Notes written in logs by coaches also capture instances where a teacher was absent from the Learning Labs and needs assistance to catch up on content.

Survey data compliment the reports of shifts in math content knowledge according to both teachers and coaches:

Now, we are not focused on the number of numbers that the child knows, now we are focused on the learning process and ensuring that they have a firm holding on the concept of a number. - Teacher 819

Here the teacher describes shifting from a focus on memorization to a focus on conceptualization. Relatedly, Coach 24 notes a change in the breadth of math content, explaining “[Coaching] expanded [the teacher’s] view of what math is beyond counting and naming shapes.”
In an Instructional Leader Consultation, a coach notes “bring it back to the BI”s” as an important coaching move the Instructional Leader noticed her employ. The term “big ideas” is referred to throughout all aspects of the data as the coach works to improve teachers’ math knowledge by continually reminding teachers to stay focused on the math content. For example, in one log the coach describes working with a teacher on an activity called “Hoop Game” which involves children throwing beanbags at a hula hoop and subitizing (naming the quantity without enumerating) how many landed inside the hoop and how many landed outside the hoop. The coach notes needing to remind the teacher of the math purpose behind the game along with the “teacher interactions” the teacher should use to highlight them for the children, explaining “otherwise it’s just tossing beanbags.”

**Knowledge of HOW to Teach it (Instructional Methods).** Each coaching cycle focused on a new “research lesson” as a common example of a method for interacting with children around specific “big ideas.” Of all shifts coded in the data, teachers most frequently describe how coaches helped them change the way they teach math both with new mindsets and specific activities. As Teacher 591 explains, “this entire experience has enlightened me to the potential of math – be open and flexible to the children’s ideas and their thinking.” Moreover, Teacher 819 commented: “The skills and knowledge that we gained through coaching are the knowledge and implementation of math games, integrating songs with numbers, and we generally engage them more in mathematical thinking.” Coach 21 also describes new teaching approaches as an outcome of coaching:

I know some teachers talked about thinking about math differently as a result of the coaching - they realized that children are capable of discovering math strategies on their own and with one another vs. being told how to solve a problem… Others realized the importance of having children talk about math and justify their thinking and really listening to them to understand, vs. just focusing on getting the right answer.
The shift in instructional methods includes a movement away from teacher-controlled lessons to those that invite children’s ideas.

**Knowledge of WHO is Taught (Child Development).** Since the intervention focuses specifically on three- to five-year-old children, knowledge of developmental levels is embedded into the “big ideas.” Teachers comment about children more often in survey responses than coaches:

> Coaches helped teachers think about ways to make our number sense activities make sense to the children and ways to help clarify and understand activities that give them good learning objectives appropriate for their age level. (Teacher 702)

Coach logs mention specific students and their different levels of understanding, and prompts push teachers to think about evidence of student learning they and the coach will watch for:

> “What will teachers look for to tell if the Big Ideas thinking is activated in the children?” Notes in logs show coaches help teachers focus not just on child engagement, but evidence of children’s understanding. For example, one coach wrote about a missed opportunity: “Teachers focused on how the children did, not what they understood” (Group Coaching Reflecting Log, Center 101, Cycle 1; underlining original).

**Integrating Knowledge of What, How, and Who.** In summary, a quote from Teacher 681 demonstrates how these three forms of knowledge interact:

> [W]e learned to set clear goals for the children about Math [what]. We learned to be patient and give children time to understand the concepts [who]. We also learned about sorting and representing numbers in different ways [how].

Shifts in teachers’ knowledge include an integration of increased math content understanding, an assortment of new instructional methods to choose from, and deepened attention to children’s developmental levels and ways they demonstrate understanding.
Shifts in Practice

Shifts in practice include implementation of new teaching strategies, addressing “weak spots” in a teacher’s practice, and persisting in incorporation of new approaches.

**Implemented New Strategies.** Group Coaching Planning Logs ask, “What might teachers do/say to help activate Big Ideas thinking?” Many of the comments in this section relate to the “teacher interactions,” which act as a list of pedagogical choices teachers can use to help children notice and think about the math in activities (see Appendix P). For example, one coach jotted down Teacher 875’s words in response to this question during a reflecting conversation: “Descriptive language is the most challenging interaction… I want to be more precise in what I say and how I say it.” Likewise, Coach 24 said in a survey, “[Coaching] increased their repertoire of teacher interactions beyond asking questions. For example, using Say what you see. See mistakes as opportunities for learning and not just as something to correct.” In order to shift practice, coaches (a) offer teachers a menu of strategies during the planning conversation; (b) allow them to choose which they believe would make the most impact; (c) encourage them to try the strategy during the lesson; and (4) offer feedback on their implementation during the reflecting conversation.

**Addressed a Weak Spot.** “Weak spots” (Chen & McCray, 2012) in teaching are addressed throughout the coaching cycle: during the planning conversation as teachers role-play with feedback from their coach and colleagues as described above; during the lesson with children when coaches might offer a suggestion or ask a question in real-time; and most explicitly during the reflecting conversation which revolves around what went well during the lesson and what can be improved.
Planning Logs prompt coaches to ask, “Which teachers are and are not okay with the coach stepping in to provide live coaching?” Most often, this is left blank since it is toward the end of the form. When coaches do have notes in this section, teachers are almost always open to this form of in-the-moment feedback to address “weak spots” as they occur. If the teacher is not okay with real-time coaching, it usually is noted only during the first cycle and they are okay during subsequent coaching cycles. The nature of the logs does not allow for detailed information about what occurs during live coaching. In surveys, teachers reflected upon the spontaneous help from coaches, reporting “you get one on one assists” and “the coach was by my side.”

Forms used by coaches to collect data during the observation also include the prompt, “Describe a missed opportunity to integrate Big Ideas into an interaction.” Reflecting conversations are designed to address this with the question, “What changes might the teaching team make that will help make the Big Ideas more clear for the children?” Answers within the available data relate to logistics such as materials or student group size and using more of the interaction to bring out the “big idea.”

Persisted in Incorporation of New Practices. The Whole Teacher Approach (Chen & McCray, 2012) describes teachers’ persistence in the incorporation of new practices; shifts in this category were less present in the data than other practice-related shifts. Coaches are prompted to ask, “How have things been going since the last cycle” as the opening question. This section is often left blank or with general comments such as “still doing weekly” and “we are extending the activities and leaving them out in areas for children to use when they want,” or logistical updates such as “they only received three or four treasure bags [from families for a sorting activity].” In one instance, a coach notes: “teachers have not done anything else with the sorting station
[activity]. They have put it away and moved on to other activities; didn’t see need to continue” (Center 101, Cycle 2, Classroom 301). In their survey response, Teacher 882 suggests an idea for improvement, “To review each activity before diving into the next one during the Learning Labs.”

**Shifts in Dispositions**

Shifts in dispositions include positive attitudes about math, beliefs that math is important in early childhood contexts, and confidence in teaching math to young children.

**Attitudes.** Although logs do not prompt coaches to inquire about teachers’ dispositions, comments regarding positive math attitudes are noted, such as “really excited about math work” (Group Coaching Log, Center 116, Cycle 3, Classroom 348). Teacher survey responses, including “The coach was awesome. She made it exciting” (Teacher 698) and “we gained new strategies to help make math enthusiastic” (Teacher 954) show further evidence of positive attitudes. In addition, how children respond to activities plays a role in teachers’ dispositions. As one coach noted in a log: “Very likely they will integrate. They see kids respond in positive ways so they keep going,” suggesting that attitude plays a role in motivation to work toward change. Comments are not linked to formerly negative statements, however, so it is unclear if the teachers always felt this way or if coaching had an impact.

**Beliefs.** Direct references to beliefs about the appropriateness of math for young children were not found in the data. That is, participants did not use variations of the word “belief” or synonyms, nor did they allude to whether or not they felt the subject belongs in a preschool classroom. An associated theme emerged in which teachers reported engaging children in more opportunities for mathematical learning. Including more math in the classroom suggests that
teachers believe it is an important content area for young learners. Participants commented about increased frequency:

- We do a lot more daily math in the classroom related to what we learned. - Teacher 863

- We were able to set up activities and use math language that we were not used to using. Now there is math happening in the class everyday as opposed to before we rarely unless needed touch on math concepts. (Teacher 821)

as well as including math across teaching modes and locations:

- We know to include math (and literacy) in every lesson plan, and we've been able to (post-labs) incorporate big ideas into large and small group activities, and even in less structured activities like dramatic play and blocks. (Teacher 674)

- We learned to engage children in math behavior every day indoor and outdoors allowing them to respond to teachers prompt. (Teacher 979)

Increased time spent on math implies an increased recognition of its importance. Likewise, coaching logs also capture teachers’ belief in the importance of math in their efforts to involve families in math learning through Game Nights and sending home math rich books.

**Confidence.** References to teachers’ confidence within the data directly attribute this shift to the work of the coach. In a survey response, an assistant teacher who refers to herself as “a teacher 3” actually uses the term “confident” and credits her coach:

- I felt that the coach helped me become more confident as a teacher 3, sometimes we feel that we don't make a difference but with this training I felt that we were all on the same page receiving the same training. (Teacher 450)

Another teacher contends that due to coaching:

- We have become more comfortable in incorporating the games and activities… (Teacher 875)

Notes from a coach’s log highlight the impact of the group coaching format:

- Teacher 618 seemed apprehensive about the game at first, but as she tried it, she became more confident. Having Teacher 523 observe and offer comments when Teacher 618
In another example, a coach captured a teacher’s experience with role-play during both coaching and the Learning Lab leading to greater confidence:

[The teacher] felt she had more confidence because she had practiced at the Learning Lab and then we had practiced and anticipated children’s thinking too. Practicing is very helpful for her. (Group Coaching Reflecting Log, Center 101, Cycle 4)

Overall, coaching appears to have the most direct impact on confidence compared to other dispositions.

**Specific Example: “Say What You See”**

In order to illustrate how these shifts operate together, two specific examples frequently mentioned in the data will be explored. First, a common theme emerged across centers regarding the teachers’ habit of asking children many questions without first offering language that helps children attend to the math goal.

We discussed the over use of questioning and to break the habit of over questioning and instead using say what you see, with re-voice and continue checking with children. (Mixed Group Coaching Log, Center 105, Cycle 2, Classroom 330)

They generally asked a lot of questions more than using any other teacher interaction. They could spend more time stopping and looking and waiting. (Group Coaching Reflecting Log, Center 118, Cycle 1, Classroom 310)

Saying what you see is a good practice to break the habit of asking so many questions. It reinforces that number name/quantity connection. (Group Coaching Reflecting Log, Center 128, Cycle 3)

[Teacher 404] ‘say what you see’ felt uncomfortable but continued to try. Felt children needed more challenge so used more questions as provocation the 2nd time. (Group Coaching Reflecting Log, Center 101, Cycle 4)
These four examples show a variety of coaches working with different centers and in different coaching cycles all suggesting teachers refer to the “teacher interactions” list to try other strategies that may scaffold children’s learning before asking open-ended questions.

In survey responses, teachers mention the “Say what you see” strategy most often compared to other “teacher interactions” but it unclear from the available data if they internalized the coaches’ message to reduce the number of questions. One teacher does point to a need to balance the interactions for the sake of students’ understanding:

We are now more intentional in our math planning as well as how we teach new concepts. We focus on the “teacher language” skills such as “say what you see” or “asking questions” to make sure our children are getting the most comprehensible input. (Teacher 645)

This emerging theme around balancing questioning with precise language highlights the intersections of different aspects of the Whole Teacher Approach in the work of coaches. “Say what you see” in an example of knowledge of how to teach. In the Teacher Interactions to Build Mathematical Thinking Document (see Appendix P), “Say what you see” is defined as follows:

Based on careful observation and hypothesis, use precise language to describe what you see, then check for confirmation. Provide labels to actions or structures that are mathematical. Children are engaged in mathematical behaviors many times during the day; language gives the opportunity to replicate what was done and to talk about it with others. Language gives you the materials to critique the reasoning of others.

And the following example is given:

I notice that you have put several brown jungle animals in a group with dark brown bottle caps. I also notice that the Legos and the fruits are either red or yellow. I wonder why did you put those objects together.

In another log, a coach reminds her teacher of the knowledge of what to teach to help her see the reasoning behind the pedagogical choice:
[the teacher] thought using ‘say what you see’ the first round [of the game] and ‘asking questions’ the second round. We planned how to keep the focus on the math. (Group Coaching Log, Center 101, Cycle 4, Classroom 300)

Additionally, teacher dispositions play a role in incorporating this new knowledge and practice. In her survey response, Coach 24 reflects on an instance when a teacher opened up to her and admitted, “During the reflection a teacher reflected on how hard it was for her to use ‘Say what you see’ because she did not really know what to say and felt she sounded silly.” Using new teaching approaches confidently may depend upon having a strong understanding of knowledge. Relatedly, data presented to teachers during reflecting conversations helps them hold a mirror to their practice so they come to their own understanding rather than feeling judged by the coach. In a Reflecting Log from Center 105 (see Figure 11), the coach notes in response to the prompt “What did the teachers notice about the data that was collected?” that they are asking questions a lot and not using “say what you see” or “descriptive language.”

Figure 11. Excerpt from Reflecting Log, Center 105, Cycle 1

Furthermore, in notes on an Instructional Leader Consultation log recorded after completing coaching Cycle 1 at Center 118, a coach commented that the Instructional Leader “felt this went well but she had expected it to be easier, but for teachers it was a lot more difficult
to use the Interactions when they had to use them to get to the Big Ideas. She thinks they may feel overwhelmed...” Integrating big ideas (the what) with interactions (the how) while maintaining confidence in their teaching practice is challenging and demonstrates why a coach is needed to provide support.

**Specific Example: Subitizing**

Another theme that emerged from the qualitative data regards a concept called “subitizing” or quickly recognizing small quantities without needing to enumerate. As defined by one of the “Big Ideas of Number Sense” from the *Big Ideas of Early Math* book, “The quantity of a small collection can be intuitively perceived without counting.” For example, when playing games that involve dice, adults and experienced children instantly recognize the quantity of dots they roll without needing to count each dot one by one. The ability to subitize only works with small quantities, relies on repeated exposure, and varies depending upon the arrangement (for instance, five items in a straight line are more difficult for most people to subitize than the common die arrangement). Both counting and subitizing are important skills to develop, but classroom teachers and parents usually focus only on counting. As one coach records during a conversation with teachers, “subitizing was new and thinking about it has created a new thinking and awareness about numbers and subitizing” (Coaching Log, Center 113, Cycle 3). Relatedly, Coach 24 explains: “The idea of subitizing provoked a lot of cognitive dissonance but I think that by the end of the intervention some of the teachers began to understand it.” The Group Coaching Logs capture a teachers’ misunderstandings such as:

[The teacher] is half-way there to understanding the Big Ideas but she wasn’t at the Learning Lab; with more time and experience she will understand... she used cards w/larger quantities [because] she felt her students already know these numbers, which is too advanced for the children. (Group Coaching Planning Log, Center 100, Cycle 3)
In this example the teacher uses quantities that are too large to be perceived intuitively. Even most adults can only perceptually subitize quantities up to five and teachers struggled to stick with small quantities. Another teacher at the same center also encounters this challenge as well as others:

[The Teacher] modified the activity again with harder arrangements (5), holding the card up longer, and asking children to show on 2 hands even though we had talked about keeping numbers small and showing on just one hand; what if you had not held the card up so long? Do you think that had anything to do with them “getting” it? Explain that card was to be brief so they’d subitize (2nd Big Idea)… need to make sure card is visible & fingers are not covering dots: watching so following her lead; did she have them count because they didn’t “see” it? Why not use a smaller number? When they couldn’t just “see” 5 in an odd arrangement, why not show a traditional 5 or just a smaller number? Remind them that focus is on smaller numbers and one hand for now & that it’s not a counting (it’s subitzing!) and not a “teaching” activity… (Group Coaching Reflecting Log, Center 100, Cycle 3)

The lesson described above is a Dot Card Transition. It involves “quick looks” in which dot arrangements are held up briefly and children are asked to replicate the quantity with their fingers before transitioning to a new activity. When the teacher holds up the card for too long, it allows children time to enumerate the dots one-by-one, thus detouring from the focus on subitizing that is the purpose of the activity. Rather than increasing the quantity, a greater challenge can be introduced by varying how the dots are arranged (three dots can look a triangle or a right angle or a straight line). Coaches also help teachers think about the language they use:

…missed many opportunities with the [Big Ideas]. When a child said “3”, she just said “yes” - she wasn’t naming the set nor affirming their ability to subitize. She seemed to be asking children “how many” were inside/outside a lot but was not saying what she saw. (Instructional Leader Consultation Log, Center 118, Cycle 4)

Here the children are engaged in an activity called Hoop Game where they toss beanbags at a hula-hoop on the floor and subitize the quantity that lands inside the hoop and the quantity that
lands outside the hoop. The coach suggests re-voicing the quantity children name and modeling subitizing when children do not answer “how many” without counting.

As demonstrated in these examples from coaching logs, coaches seek to shift teachers’ knowledge. In this particular situation, teachers require three types of knowledge: content knowledge that subitizing is an important math skill to engage children in (as opposed to just counting), knowledge of instructional methods that present rich opportunities for children to encounter subitizing such as the Hoop Game and Dot Card Transitions, and also knowledge of child development to understand which quantities and arrangements children may be able to recognize. Coaches also work to shift teachers practice by encouraging them to implement new strategies such as emphasizing the child’s ability to quickly recognize what they saw; simply asking “how many” may prompt them to count rather than subitize, for example. Working with a coach to observe their teaching may allow teachers to recognize weak spots through clarifying misconceptions. Confidence in their own math skills and a belief in the importance of improving are also necessary. As Teacher 757 remarks, “I love the joy of seeing my students identifying numbers with the subitizing games.” Coach 24 summarizes this change process and hypothesizes reasons behind the shift:

I worked with two teachers who had never heard of subitizing. Through our PD and on site coaching the teachers were able to implement the use of subitizing games and even create some of their own. They also were able to carry out the dot card routine with thoughtful use of the dot cards. I believe their interest in the work combined with the professional development, role-playing during coaching, interactions during the on site observation and reflection conversations were instrumental in the effectiveness. Also the activities, games and dot cards, were simple to initiate and weave into their daily routines. They also quickly were able to connect to understanding this big idea.

The combination of learning about the “big idea” of subitizing and simple lessons that were easy to integrate and personalize (content knowledge), thoughtful choice of powerful pedagogical
interactions (practice), and coaching support that increased interest and built confidence (dispositions) all led to a shift in teaching.

**Shifts in Relationships among Colleagues**

The final part of Research Question 2 seeks to uncover new themes independent of the Whole Teacher Approach that emerged during coding. A clear theme is shifts in relationships among colleagues, including working more closely within and across classrooms as well as assistant teachers feeling included. Much of this was described in detail in the section on Collaboration above.

Building upon the earlier findings, the coach’s direct role in facilitating this collaboration throughout the coaching cycle became clearer with the inclusion of the logs from Group Coaching and Instructional Leaders Consultations within the dataset for Research Question 2. For example, two different coaches discussed the importance of purposefully including both teachers during coaching conversations:

[The Instructional Leader] noticed that I was intentional about making sure everyone had a voice involving all teachers by asking for their opinions. She felt this was important so that no one could dominate the conversation + it helped even the quieter ppl [sic] to participate. By having all engaged + sharing, more ideas are brought to the table. (Instructional Leader Consultation Log for Center 101, Cycle 1)

the teachers all work well together. [The Instructional Leader] needs to insure that both teachers have an equal voice in planning and reflecting. (Instructional Leader Consultation, Center 128, Cycle 5)

Additionally, a coach captured an incident in which two teachers in the same classroom advanced their knowledge of what to teach and how to teach it through observing each other during the lesson and reflecting together:

I think they understand the Big Ideas much better after the reflection. Willing to share what each other did/ could do next time. [Teacher] saw when [their co-teacher] used Say
What You See + wants to use it more. (Group Coaching Reflecting Log, Center 118, Cycle 4)

Finally, one log highlights the involvement and progress of a teaching assistant:

The team is thinking about their language and how to best engage children in the Big Ideas. The assistant is noticing and taking advantages of opportunities to highlight the BIs to children. Example – while on the carpet in a circle, the children started noticing each other’s shoes, had the children group themselves by attributes of their shoes. (Mixed Group Coaching Log for Center 101, Cycle 2, Classroom 300)

The wording “taking advantage of opportunities to highlight Big Ideas” suggests this may have been a spontaneous application of the teacher learning from the intervention rather than a planned lesson.

In summary, collaboration is an additional coaching-related outcome suggested by participants. Data reveal that the coach plays an active role promoting collaboration by ensuring teachers equally participate in coaching conversations, encouraging teachers to learn from one another’s teaching decisions, and through using question prompts that ask how teaching teams will work together to accomplish next steps.

Research Question 2b Summary: Participant Perspectives on Shifts in Knowledge, Practice, and Dispositions

In summary, language from the Whole Teacher Approach framework was used to uncover how teachers discuss shifts in their knowledge, practice, and dispositions within the qualitative data including survey responses and coaching logs. Coach and teacher perspectives point to the greatest potential for shifts in teachers’ knowledge. This includes integrating (a) awareness of effective instructional methods in the form of “research lessons” and “teacher interactions;” (b) knowledge of important math content in the form of “big ideas;” and (c) knowledge of child development with attention to children’s mathematical sense-making.
Participants describe shifts in practice that focus on the “teaching interactions” and the precise language they will use to explore “big ideas” with students. Role-play was used to implement new teaching strategies and data collection combined with direct feedback from coaches addressed “weak spots” in teachers’ practice. There was less evidence of persistence in incorporation of new practices from one coaching cycle to the next. While coaching protocols and logs do not prompt coaches to directly address dispositions, evidence of positive attitudes toward math were noted but cannot be directly attributed to coaching. Teachers do not explicitly report shifts in their beliefs but do describe increased opportunities for math learning, which suggests that teachers believe it is an important content area for young learners. Mentions of changes in teachers’ confidence within the data directly attribute this shift to the work of the coach. Two specific topics that were frequently referenced by both teachers and coaches, “say what you see” and “subitizing” demonstrate how knowledge, practice, and dispositions operate together toward whole teacher change. Finally, coaches and teachers explain that coaching also shifts relationships among colleagues, allowing assistant teachers to have greater involvement in planning for and leading teaching.

Research Question 3: What Factors Facilitate and Inhibit the Outcomes of the Coaching Process?

When qualitative data were analyzed for possible factors that may facilitate or inhibit outcomes of the coaching process, four main themes emerged: (a) the instructional leader’s involvement in coaching; (b) the relationship between the coach and teachers; (c) on-site, real time coaching; and (d) logistical complications including coverage, absences, time, and engagement. Factors that facilitate the coaching process often have an opposite factor that inhibits the coaching process.
Instructional Leader Involvement

The Collaborative Math model is designed to involve instructional leaders in coaching, and the qualitative data suggest ways in which this both facilitates and inhibits coaching outcomes. Depending on the center, an instructional leader might be the site director or another lead staff member who plays a role in supporting teachers’ lesson plans and classroom practice often with the title “Education Coordinator.” Half of the centers in the intervention involved two leaders. Instructional leaders attend Learning Labs alongside teachers, as well as additional Leadership Academies designed to deepen their math content knowledge and strengthen their coaching skills. For each coaching cycle, instructional leaders are required to participate in at least one teaching team’s planning conversation, lesson observation, and reflecting conversation. Before and after each of these meetings, they collaborate briefly with the coach in an Instructional Leader Consultation to plan and reflect. The ultimate goal is for coaches to gradually shift more responsibility to instructional leaders so that center changes toward improved math teaching and learning can be sustained once the intervention concludes and coach visits cease. As discussed in detail in the quantitative results for Research Question 2, each Instructional Leader’s involvement in the intervention varied widely with representative scores ranging from 15 points to 52 points, with an average of 31.7 points. In the qualitative data, teachers and coaches discuss both benefits and limitations of their participation.

Benefits of Instructional Leaders Joining Coaching

An unexpected theme emerged from teacher responses regarding the benefit of the presence of the instructional leader during coaching observations:

It's nice when supervisors can see what I am doing and what I am learning, and how well I do. (Teacher 709) (Lead, Center 128)
Having the instructional leader at the coaching session is important. I like it because the instructional leader got to witness or be apart of what we learned. In that sense the instructional leader get [sic] an understanding of the importance of math in preschool and how to implement it. (Teacher 698) (Assistant, Center 122)

Involving the instructional leader may facilitate outcomes for teachers because they feel motivated by the opportunity to demonstrate their learning and improved teaching abilities to their supervisor.

Teachers also value the additional feedback and support the instructional leader can provide such as clarifying coach suggestions and supplying missed information. The benefits of my instructional leader sitting in on a coaching session was beneficial if I missed some important information or did not understand something that the coach was telling me. (Teacher 988) (Assistant, Center 118)

and providing an additional set of eyes and ideas:

The benefits were to have more than one person see how we implement math and to provide us with different techniques. No limitations. (Teacher 843, Lead, Center 100)

The benefits is that we had more than one person [give] suggestions on how we can improve our usage of the activity and games on the classroom. Another benefit is that the instructional leader was able to listen to our questions and concerns if there was any for that observation. (Teacher 875) (Assistant, Center 128)

By participating in group coaching meetings, the instructional leader becomes an additional partner in problem solving who remains present onsite when the coach is no longer available.

[The Instructional Leader] was informed and was part of the coaching, therefore, she was able to support us throughout the program. (Teacher 971) (Lead, Center 118)

… having my leader sit in was a great benefit for us because like I said it was good to get the extra feedback and different points of view of others. Also seen [sic] the outcome of our planning and actually seen the progress was also very helpful. It even helped us teachers see where we needed help in and what we needed to do more as far as the teacher interaction checklist. (Teacher 873) (Assistant, Center 118)

Overall, participants find benefits from instructional leader involvement including help clarifying content information, multiple suggestions for improving practice, and an additional
listening ear for questions. Knowing their supervisor thinks the intervention is important may encourage teachers to value the work and thus dedicate more energy to improving their teaching.

Support from instructional leaders also occurred in the form of materials for lessons and furthering school to home connections:

… she was able to hear what we needed from her in order to do the math games in the classroom. If we needed any supplies she was able to order them. Also, my instructional leader planned parent activity nights that helped parents understand what the kids were learning in the classroom. (Teacher 664) (Lead, Center 103)

Instructional leaders could also mediate between teachers and their Collaborative Math coach by supporting their teachers if there was a disconnect:

My instructional leader was better able to advocate for our teaching methods and our prerequisite knowledge. (Teacher 896) (Lead, Center 118)

Additionally, coaching logs capture instances when the instructional leader’s presence was beneficial:

It was very helpful to have [the Instructional Leader] in the room while planning. We were able to get immediate clarification on regulatory issues (“I can’t do that [because] it’s not allowed”) and some direction on the discrepancies [between this intervention and another one] some teachers are struggling with. Great to have [the Instructional Leader] say “[your coach] is here—do what you need to do get the best coaching experience you need!” (Instructional Leader Consultation Log, Center 128, Cycle 5)

In this example the Instructional Leader used her supervisor position to clarify a regulatory issue and offer direction on perceived differences between the Collaborative Math intervention and another initiative the teachers were involved in. The instructional leader’s presence may help reduce the time teachers spend worrying or venting, thus allowing coaching sessions to be more productive.

Likewise, coach survey responses focus on how the instructional leader’s involvement increases collaboration:
A benefit of having the instructional leader sit in on the conversation is that the instructional leader becomes part of the common conversation that the teachers are creating which, I believe, builds more of a learning community. It puts the instructional leader in a different dynamic with the teachers. I think it also helps the teachers feel more supported as well. (Coach 22)

While benefits include allowing teachers to demonstrate their abilities and feel supported, there are also limitations that may inhibit coaching outcomes.

**Limitations of Instructional Leaders Joining Coaching**

Teachers also reported limitations of having their Instructional Leader present at coaching conversations. Nervousness was a common theme:

…with her being there it made me nervous. (Teacher 555) (Lead, Center 110)

I was nervous and wasn't as natural as I would have been if I were alone. (Teacher 480) (Assistant, Center 113)

Most of the time nervous and feeling like you are being evaluated. (Teacher 936) (Assistant, Center 115)

Since Instructional Leaders fulfill a supervisory role, their presence may stifle some teacher’s participation during their coaching conversations. This is further complicated by the fact that many teachers already feel anxiety around math as a subject.

The limitation to having my instructional leader sit in on the coaching session was added pressure because it was difficult for me to learn how to teach math concepts in new ways. The benefit was having another person in the room for better clarity. (Teacher 728) (Assistant, Center 115)

The limitations can also be intensified if the teachers do not feel supported by their leader.

The limitation is that we could not be completely honest about the lack of time we were provided to work on skills or about the level of support we were receiving from our instructional leader. Since she is my supervisor I was not comfortable sharing some suggestions that I would have been if it were just my teaching team and coach. (Teacher 645) (Lead, Center 115)

Survey data show that coaches are cognizant of these limitations. According to Coach 20,
“…some teachers felt as if they were being evaluated and it made them feel self conscious.”

Coach 22 remarks that “it takes time for the new dynamic to be trusted” and notes that it may depend on the particular instructional leader and their relationship with different teachers.

Coaches also find that the presence of the instructional leader can inhibit their ability to provide effective coaching. The same log that described a benefit above, also recorded a limitation:

We had a little bit of a disagreement here-- I proposed picking one or two coachable items that would be of high impact to address with the teachers. [The Instructional Leader] had a hard time, feeling like it was needed to point out all the teachable moments that were missed. I encouraged her to at least ask the teachers about their instructional choices before talking about any missed opportunities – along with starting with the positive. (Instructional Leader Consultation Log, Center 128, Cycle 5)

In this example, the coach and instructional leader experience a difference of opinion in how best to guide the teachers during their reflecting conversation. Collaboration across multiple relationships including supervisors and their employees all at once can be a complex endeavor for coaches.

To summarize, the data include limitations that result from involving instructional leaders in coaching conversations. For teachers, these include increased nervousness, added pressure, stifled participation, and a barrier to forming a relationship with their coach for teachers. For coaches, this includes coming to agreement on coaching approaches and forming relationships with many staff across levels of professional hierarchy all at once.

**Role of the Instructional Leaders’ Relationships with Teachers**

Upon further analysis, comments about the benefits and limitations of having an instructional leader sit in during coaching conversations and observations were found to cluster around particular centers. At centers where teachers describe benefits, they do not mention
limitations or mention them less. At centers where limitations are frequent or discussed in depth, benefits are also mentioned. This suggests that the leadership styles of particular instructional leaders and their unique relationships with individual teachers may play a role. Both lead and assistant teachers describe benefits and limitations equally, suggesting the teacher’s position does not play a role.

In conclusion, the presence of the instructional leader may facilitate outcomes by motivating teachers who are eager to demonstrate their new learning and teaching skills for their supervisors, but it may inhibit teachers who are insecure about being evaluated.

**Coach and Teacher Relationships**

The quality of relationships between coaches and teachers may also facilitate or inhibit outcomes. A question on the teacher survey asks, “How would you describe your relationship with your Collaborative Math coach?” Responses were coded as positive, negative, or neutral and both researchers reached agreement. Overwhelmingly teachers characterize their relationship as positive. Of the 64 teachers who answered this question, three gave a neutral response and one gave a negative response (to be elaborated upon below). To further understand the positive responses, frequency counts were applied to words commonly used by teachers and similar words were grouped together. Since teachers used multiple terms in the same response, frequency counts cannot be viewed as a percentage of teachers who used them but instead provide a picture of the most notable coach qualities that stood out overall to teachers at the conclusion of the intervention.

*Positive*

When asked to describe their relationship with their coach, teachers most often used the term “helpful” which appeared 20 times. These next highest terms were related: “great” which
was used 13 times, “good” which was used 8 times, and “awesome” which was used six times.

Next most frequent were variations of “helpful” including “supportive” which appeared six times and “encouraging” which appeared 4 times. Teacher 716 describes an example of a positive characterization of the coach and teacher relationship:

She is AMAZING! I really loved her and she really was very helpful and taught me so many things. I admire her and she really inspired me to keep educating myself to pursue higher possibilities. She inspired me to do more math in many everyday activities. She was such a pleasure to have and I hope to work with her again.

Other positive terms used to characterize the coach and teacher relationship include “personable,” “available,” “informative,” and “impressive.”

Neutral or Negative

In contrast, Teacher 936 responded to the question to describe their relationship with their coach with “okay.” Teacher 674 explains that she felt more comfortable with her Learning Lab instructors than her coach and describes the coaching relationship as “professional.” Teacher 860 adds a third neutral characterization focused on the lack of coaching: “I missed 1st session and somehow she skipped me once or twice for unknown reasons.”

In response to the survey question about their relationship with their coach, Teacher 896 gives a negative characterization:

I felt as though she wasn't willing to get to know our classroom, our students, our teaching practices and philosophy, which made the coaching that much more difficult… I don't think she acknowledged any previous knowledge any of us had about teaching math to early learners, and therefore didn't help us build on that prerequisite knowledge… [she needs to] practice active listening…

Additionally, in a quick four question survey called an “exit slip” administered to teachers at the conclusion of a Learning Lab, an unknown participant wrote:
My coach and I seem to be miscommunicating or not understanding each other’s perspectives, but I don’t feel like there is time/ space to discuss this. (I’d appreciate follow-up on this concern). (Anonymous Teacher, Learning Lab Exit Slip, Cycle 2)

Due to the anonymous nature of the exit slips, it is unclear if this is the same participant.

Learning Labs exit slips focus on content from the lab and do not ask about coaching so this comment is unexpected.

**Coaching Style vs. Fit**

During qualitative analysis, the researcher and assistant discussed how they hypothesized that the few neutral and one negative comment might cluster around one particular coach, thus emphasizing an issue with a particular coach’s style. A closer look at the data to see which coaches worked with the teachers quoted above did not reveal any patterns; they all worked with a different coach. In fact, other teachers in the same center as Teacher 896 who also worked with the same coach had positive characterizations of their relationship:

- My relationship with the collaborative math coach was great. I was open to talk to her about anything in the program I had questions about. (Teacher 565)

- She was always available to answer any questions and she guided us wonderfully and taught us everything she knew to improve our work flow. (Teacher 118)

- My coach was fantastic. I felt so relaxed with her. She made me realize that the way I was teaching math wasn't necessarily wrong, but just needed a new approach. She gave me that new approach. (Teacher 882)

Thus, different teachers may have different experiences with the same coach based upon individual needs and preferences, suggesting that positive relationships are a matter of good fit rather than a particular approach to coaching. A positive relationship may facilitate outcomes because it increases motivation and allows teachers to make use of support, whereas a negative one may inhibit outcomes by causing teachers to reject the coach’s support and disengage from
the work.

**On-Site, Real Time Coaching**

The model intends for coaches to travel to sites for five separate cycles of coaching. Depending on the number of classrooms at each site, on-site visits may span 2-5 days. In-person coaching facilitates outcomes by fostering teachers’ accountability to the intervention and creating immediate availability for support, but can inhibit outcomes due to the time, commitment, and logistical organization it requires, especially for centers that are short-staffed.

**Accountability**

The physical presence of the coach visiting a classroom creates accountability that encourages teachers to apply new ideas gained at the Learning Lab.

So the idea of being observed actually helped me prepare and think through how I would approach the activity and utilize the big ideas learned from the labs. (Teacher 674)

We gained accountability because we knew we were going to be observed so we really had to do the work and get the different activities going in our classroom. (Teacher 480)

In some cases, however, the teacher may only be accountable when the coach is present which could be a barrier to sustainable change:

some teacher just do for showing off, and seeing they do not implement anything during the rest of the week. Only when the coach was here, and bother me that seeing they are good teachers and don't bring those skills in a regular day. (Teacher 579)

It felt like we were constantly scrambling just to "show off" when the math coach would come to observe rather than actually integrating the new math skills into our practice. (Teacher 645)

Involvement of the instructional leader may help mitigate these effects and trying out an activity once for the coach may still be better than not attempting it at all.
**Availability**

Coaches get directly involved in classroom learning, often modeling lessons, and are available in real-time to clear-up misconceptions and answer questions as they arise. The following quotes from teacher surveys illustrate examples and results of this immediate availability:

She kept me on track at all time an [sic] was able to let you know when you was [straying] away from what you was doing. (Teacher 609)

[My coach] did not mine [sic] explaining or giving us an example or playing the game with us to make sure we knew what we was doing. (Teacher 589)

…many benefits when the coach sat in the sessions. The coach offered ideas of how to improve the activity by modeling the suggestion and participating as needed. (Teacher 581)

The ‘real-time’ coaching, as well as our reflection meetings, helped us build skills right away. (Teacher 645)

Coaches are also available outside of the formal visits via e-mail, which teachers appreciated:

she went that extra mile answering questions through emails and phone calls until we knew that it was coming altogether! She WAS EXTRA SUPPORTIVE. :) (Teacher 924)

My coach was always available even via email to answer questions. She listened to my concerns and hesitations about presenting certain math concepts to particular groups of students and she was even willing to model it for me. (Teacher 859)

This pattern of communication outside of visits was also evident in an anonymous teacher’s comment on an exit slip after the Learning Lab in Cycle 3 in response to a prompt about remaining questions: “I’ll e-mail my coach.”

Overall, the regularity of coach visits appears to motivate teachers to try out new approaches for teaching math in their classrooms, and the coaches’ presence in classrooms
allows for spontaneous support throughout.

**Logistical Challenges**

*Coverage*

Since coaching is conducted in a group setting, this requires all the adults in a classroom to leave at the same time. “Coverage” refers to finding another adult to supervise children (while maintaining mandated adult to child ratios) so that all members of the teaching team can participate in intervention inputs including on-site coaching meetings and off-site Learning Labs.

Coaches work with the instructional leader to coordinate coverage:

> [The Instructional Leader] had a coverage schedule put together to cover the day so all teachers can meet outside of the classroom for reflection and reflection conversation. (Instructional Coaching Log, Center 128, Cycle 5)

In reality, obstacles still occur including small overall staff numbers, absent teachers, or vacant positions leading centers to be “short-staffed.” In survey responses, teachers highlight challenges with coverage:

> It would have probably made it easier to ensure we had coverage to make the meetings and support to implement ideas. This generally did not occur with us. (Teacher 713)

> Our center tends to be short staffed and therefore some of our coaching visits were cut short and rushed. (Teacher 473)

> My suggestion would be scheduling a better time frame for this meetings. My co-teacher and I had meetings scheduled with our coach during the children's lunch time or the beginning of naptime. (Teacher 728)

As a result, teachers mention missing coaching meetings, feeling rushed, and losing their personal break time. In addition, the physical space of a center can also present challenges:

> There should have been a space available for us to meet to limit distractions and interruptions. (Teacher 817)

Participants report that planning and reflecting conversations took place in the classroom beside
napping children, in hallways, and cramped into small offices. Others were conducted in conference rooms or spare classrooms.

**Absence**

A lack of coverage also leads to absences from Learning Labs as two teachers described:

I was not able to participate in all the Collaborative Math labs due to a short of staff. (Teacher 979)

The only limitation was finding coverage in our classrooms during the collaborative math trainings [off-site]. (Teacher 971)

Missing a Learning Lab or coaching meeting can lead to gaps in a teacher’s content knowledge and loss of momentum toward change. Coaches report needing to spend time during group coaching conversations helping one teacher catch up due to an absence, which can set back the entire teaching team.

**Time**

Furthermore, on-site visits are also difficult for coaches to schedule since they need to coordinate across multiple sites, causing teachers to comment:

having a set schedule of dates for our meetings instead of the week before or the week of the Math coach meetings. (Teacher 458)

More communication to the teachers about when planning, observations, and reflections will be. (Teacher 480)

Teachers report frustrations with lack of awareness about coaching visit schedules. They also mention being “skipped” by their coach or feeling that they did not have enough time together.

This year could have been stretched into two years. There was so much information to learn and if you truly wanted to understand and process- it takes times with a coach to ask questions and learn. (Teacher 600)

Wish we had a bit more time with them. (Teacher 873)
I found the sessions very helpful and would love to be coached more than once following each [Learning Lab] session. (Teacher 819)

My coach did an awesome job and I would have liked for more times she visited. (Teacher 786)

Survey responses from coaches echo these teachers’ sentiments regarding the lack of time and scheduling difficulties:

There was not enough time to give individual feedback. (Coach 24)

One big limitation, depending on the size of the group, is that it is often difficult to schedule regular times for teams to meet together. (Coach 21)

The group coaching sessions appear beneficial in keeping everyone on the same page and promoting collaboration, but also present challenges to adequately coach multiple teachers in a short amount of time. Even if all teachers are physically present, coaches may struggle to keep them engaged.

**Engagement**

Beyond physical absence due to coverage issues, mental absence or a lack of engagement is another factor that inhibits coaching outcomes. Teachers have job responsibilities beyond the intervention, as well as personal issues that can affect their ability to fully participate. Teachers refer to coaching as “exhausting” and explain how transitioning from a busy classroom to a coaching conversation feels “heavy.” One participant describes their multiple challenges and suggests that additional time and support are needed.

Honestly, as a classroom with one less teacher, and everything else going on (from CLASS coaching, federal review and now licensing as well as additional new requirements for the PEL teachers to complete before being off for the summer) along with MANY other factors such as reduced nap time which reduces our planning and development time, we have to prioritize and can barely complete the required elements of our job let alone plan, prepare and implement new strategies we would like to work on. Additional support in the classroom to be able to have time to plan, develop and work on implementation of new ideas within the classroom. (Teacher 713)
Coach logs include comments about teachers being distracted during reflecting conversations such as “not focused due to being tired & noisy in room” (Teacher 524), and “had a difficult child which made it hard [for them to reflect on the lesson]” (Teacher 618).

In sum, logistical challenges including lack of coverage, lack of space, absences, scheduling complications, and lack of time may constrain some of the affordances of accountability and availability that on-site visits produce.

Summary of RQ3 Results: What Factors Facilitate and Inhibit Outcomes

In summary, coaches and teachers report that the instructional leader’s involvement in coaching motivates some teachers to demonstrate new learning to their supervisors while inhibiting teachers who are anxious or feel they are being evaluated. Instructional leaders are additional partners in problem-solving, but also become another relationship for coaches to manage within the group dynamic. Styles of particular instructional leaders and their unique relationships with individual teachers may be factors for future investigation.

The majority of teachers characterized their relationships with their coach positively. Reasons for a negative or neutral characterization include a lack of acknowledgement of the teacher’s prior knowledge, miscommunication, and not meeting with the teacher regularly. Coach relationships that were negatively characterized by one teacher were positively characterized by other teachers at the same center, suggesting that positive relationships are a matter of fit rather than a particular coaching style.

Lastly, teachers shared how in-person, real-time coaching may have facilitated outcomes by motivating teachers’ accountability to the intervention and allowing coaches to offer spontaneous support during lessons. On-site coaching cycles also come with logistical challenges
that can impede outcomes due to the time, engagement, and logistical organization it requires, especially for centers that are short-staffed.
CHAPTER FIVE
DISCUSSION

This chapter discusses key findings with attention to similarities and discrepancies in results from qualitative and quantitative analyses, and with respect to the published literature on coaching in education. Implications and areas for future research are also considered.

Overview of Key Findings

The present study set out to answer: “How does math-focused coaching impact preschool teachers’ content knowledge, teaching practice, and dispositions (attitudes, beliefs, and confidence)?” Coaching is a complex endeavor, and findings offer a vivid illustration of the coaching process specific to math teaching in an early childhood context that is triangulated by coach and teacher perspectives in survey responses, notes from coaches in logs, project documents, and quantitative measures of teacher confidence, attitudes, and practice. Key takeaways from results include: (a) coaching plays a central role in improving teachers’ confidence in math teaching, particularly through the use of planning that involves role-play; (b) coaching supports teachers in deepening their knowledge of content for math teaching; and (c) inclusive group coaching with both lead and assistant teachers promotes collaboration across and within classrooms in a Head Start program. There was no evidence linking coaching dosage to teacher outcomes. Participant perspectives suggest that teachers’ practice is developing but findings did not reveal confirmation of shifts. The necessary duration for the intervention to improve and sustain new teaching practices is an area for further research. There is also an
opportunity for future studies to investigate the role and impact of involving instructional leaders in the coaching process.

**Collaborative Coaching Increases Teachers’ Confidence in Math Teaching**

The Collaborative Math professional development intervention, of which coaching was a major element, shifted teachers’ confidence in teaching math as evidenced by the intervention condition being a significant predictor of spring confidence scores. In qualitative findings, teachers directly attribute their change in confidence in math teaching to their coach. Both coaches and teachers cite the time spent planning and rehearsing lessons through role-play in a collaborative setting as contributors to this increased confidence in math teaching. In addition, qualitative results also suggest that acquiring knowledge of math content, instructional methods, and child development led to increased confidence in teaching.

Growth in participants’ confidence in math teaching is noteworthy because prior studies show early childhood teachers report higher levels of math anxiety (Copley, 2014; Gresham, 2007) and negative experiences in their own schooling background (Drake et al, 2001) that could interfere with effective teaching and even be passed down to students (Beilock, et al., 2010).

Recent research has also linked the similar construct of “enjoyment of teaching mathematics” with increased quality and quantity of math instruction for teachers working with young children (Russo et al., 2020). Thus, shifting confidence in math teaching is an important aspect of early childhood teacher professional development focused on math, and likely one that must occur in order for teaching practice to improve.

**No Evidence of Impact on Teachers’ Attitudes**

Within both qualitative and quantitative findings, the present study did not find evidence of shifts in teachers’ attitudes about math linked to coaching or participation in the intervention
condition. The ABC-PM tool uses statements about participants’ personal math experiences to capture this construct such as “I am not a ‘math person’” and “I'm good at estimating the height of objects.” Since coaching focuses directly on children’s math learning, it makes sense that it might have less effect on adult’s opinions about their own math experiences. Learning Labs do contain some adult-level math exploration, but this is not the central goal of the intervention. Taken together, findings suggest that having a positive attitude about math as an adult may not be a requirement to have confidence in teaching math with young children. Future analysis could examine how these aspects of teachers’ dispositions shift in relation to one another as a result of professional development interventions.

Indirect Evidence of Impact on Teachers’ Beliefs

The present study did not find direct evidence that coaching impacted teachers’ beliefs about math teaching. Instead, there were related indications of increased presence of math learning opportunities in terms of frequency (“now math is happening every day”), location (“indoor and outdoors”), and modes (“small group and large group”). If teachers are making new efforts to engage children in math learning, this suggests they believe it is important. These examples offer possible ideas for questions to include in future tool revisions if the developers of ABC-PM decide to continue attempting to capture this construct of teacher beliefs as part of dispositions.

Collaborative Coaching Supports Teachers’ Math Content Knowledge Development

Results reveal that the coaches in this study focused their conversations on supporting teachers’ knowledge of content for math teaching as evidenced by the frequency and richness of detail for this aspect of teacher development emerging from the qualitative data. The quantitative results for teachers’ math content knowledge, PM-PCK, are not yet available to triangulate
whether participation in the intervention condition led to measurable shifts in knowledge.

The emphasis on knowledge is noteworthy considering that teachers’ comprehension of subject matter, instructional methods, and child development are not examined as outcomes in coaching interventions in the reviewed literature, despite evidence that teachers require strong content knowledge to be effective (Ball et al., 2008; Hill, 2010) and that early childhood teachers are often not adequately prepared to teach math (Fennell, 2011; Institute of Medicine, 2015).

Even after Learning Labs designed to help teachers acquire this knowledge, coaches continued to support teachers to make sense of the subject matter and how it applied to their classrooms. Thus, this study corroborates prior research about the need for teachers to participate in contextualized coaching in addition to workshops (Darling-Hammond et al., 2017; Desimone & Pak, 2017; Kraft et al., 2018). The examples of “say what you see” and “subitize” detailed in the results section demonstrate the complexity of integrating all aspects of whole teacher change and why it may be that teachers’ knowledge must shift before their practice can. Teachers often struggled to implement these teaching approaches effectively because they had partial understanding of the “big idea” that coaches then needed to review. Successfully applying new math teaching practices likely depends upon a solid understanding of content and developmental trajectories so that teachers can draw on this knowledge to be flexible and responsive in the moment with children.

**No Evidence Linking Dosage and Teacher Outcomes**

The current study did not find evidence that the amount of time spent with their coach predicted teacher outcomes for teaching practice, positive attitudes about math, or confidence in math teaching. It is possible that effective coaching is more a matter of quality (what the coach does while with teachers) than quantity (how much time the coach spends with teachers). This is
consistent with Kraft and colleagues (2018) meta-analysis finding that neither coaching nor the combination of coaching and workshops needed high dosages to be effective. While it was hypothesized that additional time with the coach would equate to additional time for teachers to improve, it is also possible that coaches occasionally spent more time with a teaching team when the teachers were struggling in order to provide extra assistance. In contrast, coaches might have sometimes spent less time with teaching teams who more quickly integrated new learning into their practice. This scenario is especially plausible in a model that encourages coaches to ask questions rather than offer direct suggestions.

Dosage was initially identified as a variable of interest based on past studies (Germeroth & Sarama, 2017) and as a potential way to separate the influence of coaching from other intervention inputs. As qualitative analysis progressed, it became increasingly clear that coaching as part of Collaborative Math could not exist without Learning Labs as they are intertwined both in model design and participant conceptualization, which is an interesting finding in itself. In survey responses, teachers and coaches answered questions that were specifically asking about Group Coaching with comments about Learning Labs. This is likely because coaching relies upon the “big ideas” and “research lessons” teachers are introduced to during the labs. Additionally, coaches serve as co-facilitators to lead some of the labs, meaning a teacher’s coach might also be their instructor, further conflating the two intervention inputs.

Thus, it appears participants experience coaching as a direct extension to each Learning Lab rather than a separate process. This differs from how coaching is often conceptualized within the literature reviewed for this study where researchers used randomized control trials to separate participants who receive coaching from those who do not. That approach would not be appropriate to study Collaborative Coaching. The current study places coaching in focus while
acknowledging that the other inputs remain present but blurred in the background. Future studies could similarly narrow in on the other intervention inputs: Learning Labs, Instructional Leader Consultations, or Leadership Academies.

**No Evidence Linking Participation in the Intervention to Practice Outcomes**

Quantitative analysis did not find evidence that participation in the intervention condition shifted participants’ math practice after 8 months. This may seem surprising considering the promising impacts on teaching demonstrated by prior studies involving coaching. However, these studies do not consider the unique challenges and needs of early childhood teachers when it comes to math. Prior research has demonstrated that early childhood teachers often receive insufficient preparation to teach math (Copple, 2004; Fennell, 2011; Ginsburg et al., 2006; Institute of Medicine, 2015), hold beliefs that other subjects are more important (Hyson & Woods, 2014; Meisels & Howard, 2008), and have negative dispositions toward math than can impact teaching effectiveness (Beilock, et al., 2010; Copley, 2014; Gresham, 2007). Qualitative findings specific to coaching offer insight that practice may be in the early stages of development, and results suggest that teachers’ knowledge and confidence may need to shift before practice can. Past research in this specific content area for interventions that involve coaching also points to a need for an increased duration. Additionally, the construct of practice in the present study is ambitiously defined and measured through a global tool with eight dimensions that is newly developed and requires further refinement.

**Duration Limitations**

Evidence from qualitative findings suggests that practice outcomes may be developing but delayed due to the need to help teachers deeply understand the content knowledge for math teaching before they are able to translate that understanding into improved teaching practice. For
example, coaching protocols and questions on coaching logs are designed to focus conversations mainly on practice, yet both teachers and coaches shared more about knowledge and confidence in response to questions about coaching on surveys. Likewise, both quantitative and qualitative results reveal an emphasis on planning, and coaching protocols and logs have coaches begin planning conversations by reviewing the “big ideas.” Furthermore, when teachers self-report on shifts in practice within the qualitative data they often list “teaching interactions” by name without much detail, suggesting they are memorizing new terms but are not yet at the point of internalizing associated actions. Teachers also comment on logistics such as materials or student group size. These are important first steps toward making complex pedagogical choices that demonstrate teachers are still early in their progress. Collaborative Math coaches are working toward teachers’ sustained conceptual development rather than quick teaching moves, which is an ambitious endeavor. When asked how coaching could be improved, teacher participants frequently asked for more time with their coach suggesting they too sense their development is incomplete. Overall, teachers’ knowledge about and confidence in math teaching likely need to increase first before coaching conversations can narrow to influence practice as intended.

As findings from Research Question 1 confirm, the Collaborative Coaching model is complex, while lasting a duration eight months. Qualitative results specific to coaching show budding improvements such as teachers using new terminology and attempting new approaches, but this was not detected when measuring teachers’ practice quantitatively as a result of participation in the intervention condition. Additional years may be required for teachers to fully integrate math content knowledge for teaching and improve their practice. This is consistent with prior research about math-content coaching. In a randomized controlled study of math-focused coaching with teachers in grades kindergarten through five in 36 schools, Campbell and Malkus
(2011) did not find significant results after the first year. It was not until after three years that they found coaching positively affected student achievement for students in grades three to five. The authors attribute this delay to the time necessary for teachers, coaches, and administrators to work together toward “coherent collective efforts marked by active learning and focused on math content and pedagogy, as well as on student understanding.” Likewise, West and Staub (2008) suggest from their experience that Content-Focused Coaching initiatives generally take three to five years to gain sustainable momentum and show measurable results. The present study sheds light on how changes in confidence, knowledge, and collaboration may be the first steps on the longer process toward change in teaching practice.

Relatedly, interventions may cause “delayed treatment effects” and results may not be evident until more time has passed. Changes in teachers’ practice may require a qualitative shift that occurs once teachers coordinate their application of new concepts and approaches as a result of accumulated experiences across contexts. Collaborative Math asks teachers to dramatically change their approach to teaching math and they may not be able to transfer this learning into practice until they have time to revisit the “big ideas,” “teacher interactions,” and “research lessons” multiple times with different classes of students. In the words of one coach: “[The teacher] is half-way there to understanding the Big Ideas…with more time and experience she will understand…”

Measurement Limitations

Prior studies also measure teaching practice differently. The present study used total EQUIP-M scores that include three domains. First, “teacher intentionality,” considers if: (a) the activity has a clear goal for children’s learning; (b) the teacher provides context such as stories, analogies, or materials that facilitates and does not obfuscate the math ideas being taught; and (c)
the teacher uses mathematical language explicitly. Second, “teacher responsiveness” considers if: (a) the teacher looks for evidence of children’s understanding; (b) the teacher incorporates children’s contributions into the math learning; (c) the teacher changes the activity in response to children’s needs; and (d) the teacher uses student errors as opportunities for learning. Third, “student mathematical sense-making” considers if: (a) children verbalize their mathematical sense-making and (b) students display positive learning behaviors (see Appendix E for more information about the tool).

Past studies examine teachers’ use of “math mediated language” (Rudd et al., 2009), use of student work to inform instruction (McGatha, 2009), and time for math discussion (Becker, 2001) as proxies for teachers’ practice. Qualitative findings do suggest that teachers in the current study increased their use of math language as well as increased the time they dedicated to math teaching, but these were not the direct focus of the quantitative measure used in this study. Further analyses could look separately at each of the EQUIP-M tool’s eight dimensions rather than teachers’ overall scores. For instance, scores specifically for “Teacher Uses Mathematical Language to Promote Concept Development” may reveal outcomes whereas the total scores did not.

In addition, the EQUIP-M tool is new. While based upon an existing tool (Cerezci, 2020) and developed over the course of two years by an expert team of math researchers and former classroom teachers with strong reliability (Reid & Skourletos, 2020), it requires additional testing to validate its ability to accurately capture the construct of math teaching practice. This work is currently underway through a study funded by the Institute of Education Sciences (McCray et al., 2018).
Inclusive Group Coaching Promotes Collaboration

An unexpected outcome of coaching within the present study was enhanced collaboration among colleagues. Participants reported increases in joint work around math teaching within classrooms among co-teachers, as well as across classrooms with other coworkers at the same site. Examples of evidence of collaboration found in qualitative results include: (a) comparing understandings of Learning Labs, (b) discussing different ways teaching teams adapted research lessons to meet each unique classroom context, (c) learning from each other’s successes and challenges, (d) feelings of inclusiveness, and (e) group momentum to try new teaching strategies and persist through struggles with support from colleagues. Example A relates to teachers’ content knowledge for math teaching, whereas examples B and C relate to math teaching practice, and D and E relate to dispositions about math. Thus, collaboration impacts all three facets of the whole teacher framework and its related outcomes.

Collaboration was not only a result of coaching, but also an intentional design feature of the coaching model through the decisions to use a group coaching format, require participation, and include assistant teachers. Indeed, all components of the model relate back to the central theme of collaboration, especially planning for math and role-play which were emphasized by participants.

Group Coaching Format

Under the model as implemented with Head Start teachers in the present study, coaching occurs in a group format that always includes both lead and assistant teachers, and also occasionally includes leaders, in conversation with an expert coach who is a supportive outsider. Compared to one-on-one coaching, a group format is rare within the published literature on coaching in education with a few exceptions within Head Start contexts. Raver and colleagues
(2008) included Head Start assistant teachers in their intervention involving weekly coaching “from fall to spring” (p.14) that found positive increases in classroom climate, teacher sensitivity, and behavior management. A group format is also part of Practice-Based Coaching (Artman-Meeker et al., 2015; NCQTL, 2008; Snyder et al., 2015), which is recommended online in the Head Start Early Learning and Knowledge Center with accompanying professional development resources. However, PBC also involves individual coaching and does not use the group format exclusively as Collaborative Coaching does. Outside of education in the field of organizational psychology, Brown and Grant (2010) contend group coaching “has important but under-used potential as a means of creating change in organizational contexts” (p. 37).

By including all teachers together during coaching conversations, the Collaborative Coaching model redefines coaching beyond the usual dyad between a teacher and a coach to a group dynamic. The coaching process thus includes the relationship between each teacher and the coach, as well as the relationship between co-teachers as moderated by the coach. This collaborative approach also fits the reality of multiple adults working closely together in early childhood classrooms, making it a good fit for the context. Furthermore, participants discussed aspects of coaching that they found to be influential that are only possible in a group setting. These include: (a) hearing ideas from colleagues; (b) having time to plan with co-teachers; and (c) practicing “teaching interactions” while anticipating student outcomes through role-play with feedback.

**Required Participation**

Relatedly, Collaborative Coaching is a requirement for all teachers in all classrooms working with children ages 3-5 at the participating centers. This decision differs from some models in the published literature that make coaching a voluntary option that will hopefully
interest more teachers once they witness their colleague’s success (Knight, 2009). Teachers in the present study mention apprehension around coaching due to the math content and nervousness around “doing things wrong,” making one wonder if they would have volunteered to participate on their own. Yet at the conclusion of coaching, with only a few exceptions, teachers in this study reflected positively about their relationship with their coach and many voiced requests for more time together. Similarly, in some other models coaches only meet with select teachers deemed most in need of support. In fact, the wording of the Head Start Performance Standards (U.S. Department of Health and Human Services, 2016, Part 1302.92) requires centers to identify “which staff would benefit most for intensive coaching” and provide coaching for these teachers “at a minimum” (see Appendix A for the full section). Although it is not the intention, this selective approach could lead to teachers feeling that coaching is a penalty, an additional job responsibility assigned due to their poor performance as a teacher. In contrast, coaching approaches across disciplines from medicine to music to business recognize that all professionals can benefit from the attentive eye of an expert encouraging the ever deepening of one’s practice (Gawande, 2011). By involving all teachers, Collaborative Coaching is designed to leverage teachers’ strengths for the benefit of the group rather than fix single teachers who are perceived as deficient. If only some teachers are included in coaching the important results of collaboration detailed above would be lost.

**Assistant Teachers**

Involving assistant teachers arose as an important feature of the model, which is especially noteworthy as educators in this role are rarely mentioned in the published literature about coaching. While this is likely because this teaching position is specific to early childhood contexts, a meta-analysis of coaching in Head Start found assistant teachers participated only
25% of the time (NCQTL, 2008). Assistant teachers may be excluded due to budget, time, coverage, employment contract differences, and other logistical reasons, but the present study finds that their inclusion is worth the investment. Quantitative analysis did not find significant differences between lead and assistant scores, showing that the participation in the intervention condition effectively increased confidence in math teaching regardless of their role. Qualitative findings corroborate this increased confidence as well as feelings of inclusion and consistency.

As one assistant teacher sums it up:

I felt that the coach helped me become more confident as [an assistant teacher], sometimes we feel that we don't make a difference but with this training I felt that we were all on the same page receiving the same training.

In the present study, involving assistant teachers meant that they also needed to take a turn enacting the target lesson with children as part of the coaching cycle. For those who were accustomed to a supporting role, this may have been a rare opportunity to take charge of instruction with children and to push beyond their comfort zone. Participants report that coaching led to shifts in relationships among colleagues, allowing assistant teachers to have greater involvement in planning for and leading teaching. This likely contributed to increases in confidence in teaching math to young children. It is also important because prior research finds early childhood teachers have low levels of math content knowledge and more traditional beliefs about how to teach math content (Linder & Simpson, 2017) meaning that if assistant teachers are not involved, the teacher who participated in the intervention might use conflicting teaching approaches compared to the teacher who did not. For example, a teacher who has learned about subitizing might focus on quantities of five and smaller which frustrates a co-teacher who does not understand the concept and worries her co-teacher is not challenging students. Allowing all teachers to participate can help co-teachers unify their understanding and approaches for the
benefit of children, while at the same time motivating them to persist in applying new approaches when they are doing it together. It also creates more potential for engagement in math learning when either teacher can lead lessons and both have the content knowledge to capitalize upon spontaneous math rich moments such as during play time or snack time.

Under a collaborative approach, coaching can move from a singular experience that ceases once the coach leaves toward a professional habit of thinking and learning with others that may last beyond the time the coach is on site. Colleagues who become accustomed to working together to improve their math practice may eventually be able to continue in the absence of the coach. This shift in conceptualizing coaching is analogous to the differences between students individually completing worksheets with 30 problems in traditional math class settings to develop procedural understanding, compared to participating in math rich conversations about a few problems to think them through more deeply together and develop conceptual understanding.

**Collaboration Relies Upon Common Knowledge**

Before coaching even occurs, all teachers and leaders attend a Learning Lab together first to “get on the same page” in the words of one teacher. There they learn “big ideas” and “teaching interactions” which creates a shared language for co-teachers and coaches to discuss concepts. The success of the group coaching format relies on creating this common entry point upon which layers of coaching conversation can then build. In order to ensure the quality and continuity of children’s classroom experience, teachers working in the same classroom attend Learning Labs on different days. While all labs follow the exact same outline, the facilitators and participants vary and therefore the way math content knowledge is experienced and activated differs for co-teachers. Consequently, one role of the planning conversation, which begins the coaching cycle,
is to function as a collaborative moment in which coworkers can compare and contrast their takeaways from the different workshops. This process may deepen concept development and aid in building a united approach within the classroom. It also takes time, which may be one explanation for the salience of planning conversations within the results as well as lack of evidence for practice outcomes.

**Collaboratively Planning for Math**

Quantitative findings show a greater amount of total time spent in planning conversations (average of 196 minutes per teacher) versus lessons (118 minutes) or reflecting conversations (185 minutes). Qualitative findings likewise reveal an emphasis on planning, as evidenced by this component’s salience from the perspectives of teachers, coaches, and official documents. The makes Collaborative Coaching similar to Content-Focused Coaching (West & Cameron, 2013; West & Staub, 2003) compared to other approaches that do not include a planning or a preconference as part of coaching (Isner et al., 2011). Past research has found that having a content focus increases coaching effectiveness (Darling-Hammond et al., 2017; Desimone & Pak, 2017; Kraft et al., 2018) but this is less common in early childhood settings where subjects tend to be more integrated than upper grades.

The emphasis on planning and content are connected. Qualitative results indicate that Collaborative Math coaches begin their planning conversation by reviewing the “big ideas” and are constantly referring back to them in logs. This suggests that even after a three-hour Learning Lab workshop to cover the content, more review is needed to fully understand and integrate new math concepts into teaching practices that each teaching team will implement in their unique classroom. Thus, it is important to consider the subject matter when choosing or designing a coaching model.
Coaching Strategies in a Collaborative Context

Coaches, too, collaborate with colleagues through monthly group meetings and a climate of informal support in addition to individual supervision. Thus, the model is premised on having highly qualified coaches and results suggest ways coaching initiatives may train and support their coaches. Collaborative Math coaches employ strategies in their work to support teachers that are guided by official coaching protocols and forms. The four most salient strategies include: (a) emphasizing a select focal math concept (“big idea”); (b) supporting each teacher to choose a specific teaching interaction that will highlight this math concept for children, (c) practicing through role-play with feedback, and (d) collecting data to inform how well big ideas and interactions were integrated during the lesson. These data are then used to guide the reflecting conversations, once again promoting collaboration by establishing a common entry point for reflection while also guiding teachers in what to watch for when their co-teachers lead future lessons.

Another way to conceptualize the findings about coaching strategies is in comparison to Rush and Sheldon’s (2011) five coaching characteristics that led to use of newly learned skills or improvement of existing skills: (a) joint planning, (b) observation, (c) action, (d) reflection, and (e) feedback. Each occurs in Collaborative Coaching and takes on a new meaning in the collaborative context. As already discussed above, joint planning with teaching teams is a major focus, and it occurs not only between teacher and coach but also between co-teachers as moderated by the coach. The observation of other teachers occurs first in the Learning Lab through videos, again during planning through role-play, and once more as each co-teacher takes a turn leading the lesson with children that the other teacher may support. Action occurs as the lesson is led by each teacher with children and the coach collects data. In the group coaching
context, teachers have the opportunity for reflection about their own teaching as well as a chance to learn from other teachers as they consider the coach’s questions aloud together. Likewise, feedback comes both from the coach who is a math content expert as well as from co-teachers who have expertise about their classroom culture and children.

As they facilitate conversations, coaches employ a mix of questions and direct suggestions. Deciding which ideas to use and when likely depends on the personality of teachers involved, time constraints, and the topic at hand. For instance, clarifying math content may require direct feedback which the expert coach is qualified to provide, whereas choosing teaching interactions may require the teacher to take more initiative since they know their individual teaching style and students better. This balance and the coach’s choice of approach in the moment are of interest for further investigation.

**Role-Play**

Notably, group role-play was a salient component of Collaborative Coaching as reported by participants, but it is rare within the published literature. In fact, Artman-Meeker and colleagues’ (2015) review of 49 early childhood coaching studies revealed it to be the least used strategy from their list of 12 at a frequency of only 4.1%. Their definition of role-play involves one teacher and one coach, whereas Collaborative Coaching capitalizes upon the group dynamic to have each teacher take turns playing the role of “teacher” while the other teacher(s) and coach play the role of “students.” Coaching logs prompt teachers to participate in role-play at the end of each planning conversation. Teachers know to expect it every cycle, and also know it is useful as they will immediately implement what they practice for the upcoming lesson. In other models that only include a lesson observation and reflection, teachers might be less willing to practice through role-play if it is being used a for a hypothetical future lesson that their coach will not
witness. Additionally, recognizing colleagues are also being vulnerable, and even playful, might motivate teachers to participate in role-play while acting as a sort of “ice-breaker” to deepen collaborative relationships.

Qualitative findings suggest that role-play increases teachers’ confidence in math teaching, a finding supported by the positive shift found in quantitative results. Comments from coaches in Group Coaching Logs specifically mention their belief that practicing within a collaborative context led to this shift. Qualitative findings also suggest role-play is a strategy to transfer planning ideas to teaching application. Future studies on Collaborative Coaching would do well to look further into the details of its implementation and seek to track the influence of this specific technique on each type of teacher outcome.

Collaboration Challenges

Overall, the collaborative coaching approach fits the context and reality of multiple professionals who work together every day in an early childhood classroom. There are unique benefits that come from focusing on collaboration as described above, but the model is not without challenges that coaches must work to mitigate. In the group setting, coaches need to remain aware of multiple factors when making decisions about how best to move forward while facilitating the conversations. Individual teachers may need varying levels of coaching support based upon differences in content knowledge, confidence, and teaching practice as well as personalities and interest in the intervention. Coaches need to also consider the dynamics in the relationships between lead and assistant teachers. Teachers acknowledge their fears of being judged by or compared to their colleagues, and as one coach explains “it became awkward if you needed to address a specific issue.” Collaboration itself may be a new set of skills that teachers need to be aware of and practice more consciously in order to benefit children’s learning. Thus,
Collaborative Coaching needs to explicitly address classroom teaching relationships as well as math content and pedagogy.

**Instructional Leaders**

In qualitative findings, coach and teacher participants report that the instructional leader’s involvement in coaching inhibits some teachers who are anxious or feel they are being evaluated. Prior research anticipated this outcome (Aiken & Akers, 2011; Jablon et al., 2016; O’Keefe, 2017), and therefore the opposite finding, that some teachers in the current study feel motivated to demonstrate new learning to their supervisors, was unexpected. An instructional leader’s level of involvement in the intervention was not a significant predictor of teachers’ practice, attitudes, or confidence. Styles of particular instructional leaders and their unique relationships with individual teachers may be factors to study in future investigations.

The involvement of the instructional leader is a complex variable that was beyond the scope of the present study and requires further examination to understand. Instructional leaders did not complete surveys as coaches and teachers did. Instead, their voices are only represented in findings from this study infrequently in the form of their ideas or quotes in logs captured by the coaches whom they partnered with during Instructional Leader Consultations. Leaders play a larger than originally realized role in the intervention and coaching. The model intends for coaches to gradually pass coaching duties to leaders so that they can then sustain coaching their staff toward improved math instruction after the conclusion of the intervention. Leaders are prepared in a variety of ways: six Leadership Academies to deepen math content and learn coaching strategies; shadowing coaches and attending a complete cycle of planning, lesson, and reflecting sessions for at least one classroom per month; and Instructional Leader Consultation meetings with the coach in between each coaching conversation. Examining these inputs was
outside the objectives of the present study and many questions remain. How do coaches shift and balance their focus between coaching teachers and training instructional leaders? Are teachers missing out on support from their experienced math content coach in order for their more novice leader to take over? Are instructional leaders ready to be effective in this role and what do they do once the intervention concludes?

**Summary**

In sum, this study shows that the Collaborative Coaching model’s decision to require all teachers to participate and the use of a group coaching format led to increased collaboration among colleagues at Head Start sites. This approach fits a context where multiple adults interact with children in the classroom and each requires, and deserves, equal opportunities for professional development. Enacting coaching as a collaborative effort allows teachers to practice learning and thinking with others in a facilitated fashion that can then be internalized into a habit when the coach is not on site. Successful collaboration relies upon shared entry points such as Learning Lab attendance and common planning time with co-teachers. Coaches use strategies to support teachers including reviewing the mathematical “big idea,” helping teachers to choose a related teaching interaction, facilitating teachers to take on roles of teacher and student to rehearse, and collecting data during the lesson with children to inform the reflecting conversation. Throughout the process coaches employ a balance of direct suggestions with questions to prompt teachers to come to their own conclusions. In particular, the use of role-play in a group setting helped teachers build confidence in math teaching. The collaborative dynamic also includes the coaches themselves, who are highly qualified and well supported for the challenges of meeting multiple teachers’ needs within the same coaching conversation.
Implications

As Head Start centers and other early childhood education organizations meet new mandates and implement coaching with their teachers, the present study’s findings offer considerations for model choices and adaptations. Collaborative Math made a bold effort to invest in improving classroom teaching through Collaborative Coaching that includes all lead and assistant teachers at a site. The dyadic relationship common in the coaching literature does not translate well to the early childhood classroom context. In a setting where there is no such thing as teaching alone, results support the importance of collaboration both as a professional development model design choice and also as a desired outcome of coaching. The group coaching approach was essential in increasing teachers’ confidence in math teaching as well as their knowledge, both aspects that must shift before teaching practice—and ultimately children’s learning—can. Furthermore, this study strengthens the existing research base advocating for coaching by demonstrating that workshops alone are not enough, as well as the need to consider a specific content focus as part of coaching.

Beyond the practical applications, the present study also contributes to the fields of education and teacher development research in numerous ways. First, it begins to fill the void of studies related to math content-focused coaching in early childhood contexts. In doing so, it demonstrates elements unique to this subject including an emphasis on planning to increase teachers’ content knowledge and the important role of teacher dispositions. Second, the current study also highlights the involvement of assistant teachers and instructional leaders, while featuring teacher and coach voices to amplify perspectives from those directly doing the work. Third, clearly defining the coaching model in terms of underlying philosophy, components, dosage, and coach characteristics allows the field to advance toward a common definition of
coaching, while broadening it to move beyond a one-on-one dynamic when the setting requires it.

Finally, the mixed methods approach strengthens the finding about coaching impacting teachers’ confidence in math teaching as well as the emphasis on planning. Had only quantitative data been collected and analyzed, the insight into the fact that knowledge was a major focus of coaching would have been lost. Qualitative findings were also necessary to uncover the role of collaboration. At the same time, discrepancies in qualitative and quantitative findings about teacher practice outcomes lead to future questions such as how and when aspects of professional teacher growth unfold, and which is likely to shift and change before the other. What is the necessary duration for an intervention to support teacher development to the point where it impacts math teaching practice?

**Limitations and Future Directions**

As with all research, the present study was limited and offers opportunities for future directions. While strong in a mixed-methods design and measuring multiple teacher outcomes, the small sample size may have led to insignificant quantitative findings. Ideally, a three-level HLM model that also includes classrooms would best represent the data and this, too, requires a larger sample. Crucially, the quantitative data lack teachers’ PM-PCK scores to measure teachers’ knowledge of content for math teaching. Participants refer to shifts in knowledge more frequently and robustly than the other teacher outcomes and the results from this measure will need to be analyzed once available to compare. Additionally, the EQUIP-M tool, which is designed to measure teachers’ practice, will require more testing in order to be further validated. Child outcome data were also beyond the scope of the present study.

Additional limitations revolve around data collection. More information is needed to
define and understand what exactly occurs when coaches join teachers for their lessons in between planning and reflecting conversations. Measures for dosage do not capture the coach’s level of involvement during lessons which may have ranged anywhere along the continuum from hands-off observer to modeling the lesson while the teacher watched. Even in Collaborative Math documents, the term used for this part of the cycle echoes this ambiguity as it varies between “lesson,” “observation” and “enactment.” Likewise, the qualitative data include more about planning and reflecting since the logs are focused on these conversations. These logs also capture only the coach’s perspective since it is their notes. Relatedly, data may be biased based upon what coaches could jot down in the moment and may misrepresent the complexity of the rich conversation. Similarly, participants are being asked about their experience at the conclusion of the intervention; this relies on self-reflection and may omit nuances from the evolving process. The survey format also limited the ability to ask follow-up questions to clarify meaning.

Moreover, the majority of coaches report fluency in Spanish and 8% of teacher participants list Spanish as the language they speak most fluently. It is unclear if and how often Spanish was used during coaching, and it was never mentioned or used in open-ended coach or teacher survey responses. While questions did not ask about language directly, it is a part of the intervention’s design with handouts and exit slips written in both English and Spanish. It is possible that because surveys for the current study were conducted in English, teachers who are more comfortable reading and writing in Spanish may have opted out. Furthermore, coaching logs are written and completed in English, and the group coaching dynamic may require English as the default language in order for all teachers to participate even if one teacher prefers to communicate ideas and process new information in Spanish. Future research might examine the use of language supports in coaching, especially in a collaborative model.
Lastly, under Collaborative Coaching, the individual teacher is not the only unit of development but also teaching teams and ultimately whole centers. This makes it especially difficult to study as measures are designed to target teacher outcomes at an individual level whereas the model seeks to affect change at the group level. Even teacher surveys were collected individually, and it may be interesting to see the data that a focus group approach would capture as it parallels the group coaching dynamic. A measure of collaboration is an additional outcome that may also be important to develop, and therefore useful for future research about this model to consider. As research proceeds in the area of coaching, the challenge will be how to balance measuring discrete persons with examining the complex systems of relationships that exist when coaching staff through a collaborative process within educational settings.

**Conclusion**

In conclusion, the present study found that this particular math-focused coaching model, Collaborative Coaching, increases lead and assistant Head Start teachers’ confidence in math teaching. Participants also report a positive impact on their math content knowledge for preschool teaching. Results suggest that teachers’ knowledge and confidence need to shift first before coaching conversations can narrow to influence teachers’ practice outcomes as intended, and that a greater duration of more than one academic year may be needed. Collaborative Coaching is a unique model among those described in the published literature due to its combination of a content-focus with exclusive use of group coaching that promotes collaboration. The model attends to teachers’ multi-dimensional growth in terms of dispositions, knowledge, and practice in relation to the historically challenging subject area of early math. Collaborative Coaching relies on highly qualified coaches who support teachers to plan for math teaching through strategies including role-play. The involvement of instructional leaders is a
complex component that invites opportunities for future research.

In the end, Collaborative Coaching offers a novel conceptualization of coaching beyond the typical dyad to include all adults working together with children in preschool classrooms. Thus, future research on Collaborative Coaching calls for a new framework for thinking about the teaching-learning dynamic that moves away from the dyadic equation where the coach guides the learner to a group process requiring a revised conceptualization of the unit of development over time. What changes, and when changes in teaching practices and child outcomes occur, reflects the talents and efforts of colleagues in interaction with one another as opposed to the influence of a single individual. The results of the current study suggest that teachers benefit from the collaborative context for learning about their own teaching just like the children in their care benefit from learning together with and from peers.
APPENDIX A

HEAD START PERFORMANCE STANDARDS SECTION 1302.92 TRAINING AND PROFESSIONAL DEVELOPMENT
(a) A program must provide to all new staff, consultants, and volunteers an orientation that focuses on, at a minimum, the goals and underlying philosophy of the program and on the ways they are implemented.

(b) A program must establish and implement a systematic approach to staff training and professional development designed to assist staff in acquiring or increasing the knowledge and skills needed to provide high-quality, comprehensive services within the scope of their job responsibilities, and attached to academic credit as appropriate. At a minimum, the system must include:

1. Staff completing a minimum of 15 clock hours of professional development per year. For teaching staff, such professional development must meet the requirements described in section 648A(a)(5) of the Act.

2. Training on methods to handle suspected or known child abuse and neglect cases, that comply with applicable federal, state, local, and tribal laws;

3. Training for child and family services staff on best practices for implementing family engagement strategies in a systemic way, as described throughout this part;

4. Training for child and family services staff, including staff that work on family services, health, and disabilities, that builds their knowledge, experience, and competencies to improve child and family outcomes; and,

5. Research-based approaches to professional development for education staff, that are focused on effective curricula implementation, knowledge of the content in Head Start Early Learning Outcomes Framework: Ages Birth to Five, partnering with families, supporting children with disabilities and their families, providing effective and nurturing adult-child interactions, supporting dual language learners as appropriate, addressing challenging behaviors, preparing children and families for transitions (as described in subpart G of this part), and use of data to individualize learning experiences to improve outcomes for all children.

(c) A program must implement a research-based, coordinated coaching strategy for education staff that:

1. Assesses all education staff to identify strengths, areas of needed support, and which staff would benefit most from intensive coaching;

2. At a minimum, provides opportunities for intensive coaching to those education staff identified through the process in paragraph (c)(1) of this section, including opportunities to be observed and receive feedback and modeling of effective teacher practices directly related to program performance goals;

3. At a minimum, provides opportunities for education staff not identified for intensive coaching through the process in paragraph (c)(1) of this section to receive other forms of research-based professional development aligned with program performance goals;

4. Ensures intensive coaching opportunities for the staff identified through the process in paragraph (c)(1) of this section that:

   i. Align with the program’s school readiness goals, curricula, and other approaches to professional development;
(ii) Utilize a coach with adequate training and experience in adult learning and in using assessment data to drive coaching strategies aligned with program performance goals;

(iii) Provide ongoing communication between the coach, program director, education director, and any other relevant staff; and,

(iv) Include clearly articulated goals informed by the program’s goals, as described in §1302.102, and a process for achieving those goals; and,

(5) Establishes policies that ensure assessment results are not used to solely determine punitive actions for staff identified as needing support, without providing time and resources for staff to improve.

(d) If a program needs to develop or significantly adapt their approach to research-based professional development to better meet the training needs of education staff, such that it does not include the requirements in paragraph (c) of this section, the program must partner with external early childhood education professional development experts. A program must assess whether the adaptation adequately supports staff professional development, consistent with the process laid out in subpart J of this part.

APPENDIX B

TEACHER CONSENT FORM
Dear Teacher:

Your Head Start Center will be participating in a professional development program, “Collaborative Math: Creating Sustainable Excellence in Mathematics for Head Start Programs.”

We would like to invite you to participate in a research study (2016-2018), led by Erikson Institute and SRI International, to examine the effects of teacher professional development on young children’s learning. This project will allow us to learn more about the promise of the training. Before the program begins, your center will be randomly assigned to receive training services either the first year or the second year of this two-year program. If your center is assigned to receive training services in the first year, there is an additional intervention service that your center director may receive in the second year – ongoing consultation. Which centers will receive this additional service in the second year will be determined randomly.

Your participation in the research study is voluntary. As part of your participation in the study, you will be asked to provide feedback about your experience and the training components through surveys and interviews. Participation in this 2-year study also includes allowing research staff to come to your classroom and administer 2 short, developmentally appropriate assessments to up to ten children, allowing research staff to observe your teaching, and completing a 40-minute on-line survey.

Procedure. In agreeing to participate, you consent to:

- Help us seek the informed consent of the parents of children in your classroom to be assessed.
- Allow research staff to assess up to ten children once during the fall and spring of each year, about 20-30 minutes per child. Each child assessed will receive a book.
- Allow research staff to video record math lessons in your classroom in the fall and spring of your first year of participation, and then in the spring in the second year of participation (30 minute per observation).
- Complete a 45-minute on-line survey about pedagogical content knowledge, beliefs about math teaching and learning, and your center directors leadership style in the fall and spring of your first year of participation, and then in the spring of your second year of your participation ($50 stipend for each survey completed).
- **If selected for services the first year:** Complete a survey about the success & challenges of teaching math and implementing this training program at your center during spring 2017 and spring 2018 ($25 stipend for each survey completed).
- **If selected for services the second year:** complete a survey about your professional development experience in Spring 2017 and complete a survey about the success & challenges of teaching math and implementing this training program at your center during spring 2018 ($25 stipend for each survey completed).

Child assessments will be conducted by research staff with expertise in early childhood development. The assessment process involves manipulating materials and answering short questions. Each assessment session will take approximately 20-30 minutes for Pre-K children. The assessment will be conducted in a quiet location in or near the classroom. The assessment is designed to be interesting and pleasant for children, and can be interrupted and continued at a later time, if needed.
Trained videographers will record a planned math lesson for the duration of the activity, three times during each data collection period. During video observations you will not be asked to do anything specific. You will proceed with your regular classroom math activities as planned.

For the online survey, you will receive an e-mail that provides you with an ID number and a link to the survey website. In one part, you will read through a short play scenario and be asked to identify and reflect on the mathematics involved. In another part, you will be asked to answer some questions about your thoughts on mathematics teaching and learning. You will also be asked to tell us about your educational background and experience.

You will also receive an e-mail that provides you a link to a survey about your experience in this training program or other professional development experiences. You will be asked to complete questions about your experience in this training program or other professional development experiences.

**Voluntary Participation.** Your agreement to participate is entirely voluntary. At any time for any reason, you can decide not to participate in the study. Participation or declining to participate will have no effect on your employment with Head Start, and will have no effect on your current or future enrollment in any Erikson projects.

**Risks and Discomforts.** We foresee only minimal risks or discomforts for you in participating in this research. We will work with you and your staff when scheduling assessment and video recording sessions, and every effort will be made by research staff to minimize disruptions to your classroom.

**Benefits.** There are no direct benefits to your participating in these research activities. Your participation, however, will help us advance the knowledge of teacher professional development for early math.

**Confidentiality.** No identifying information on you or your students will ever be in any reports, publications or presentations of this research. Data and videos will be kept at Erikson Institute on a secured drive or online in a secure place. Access to observation and survey data is limited to Erikson Institute and SRI International project staff. The assessment results of children in your classroom will not be available to anyone outside of the research project, including all Head Start staff.

**Contact Persons.** If you have any questions about this study, you may contact the Project Director, Jennifer McCray, at 312-755-2250. In the event that you believe you have suffered any physical or psychological injury as a result of participation in the research program, you may contact the Chairperson of the Erikson Institute Institutional Review Board for the Protection of Human Subjects, Dr. Amanda Moreno (312-755-2250) or the Institutional Review Board, SRI International, 333 Ravenswood Ave, Menlo Park, CA 94025, by calling (650) 859-4022 or emailing IRB@sri.com.

**Please complete the form below, check a box to indicate whether you consent, and return the form to the Erikson Data Coordinator.**
Sincerely,

Jennifer S. McCray, Ph.D.
Director, Early Math Collaborative
Erikson Institute
451 N. LaSalle
Chicago, IL 60654
Phone: 312-755-2250
jmccray@erikson.edu

Erika Gaylor, Ph.D. and Ximena Dominguez, Ph.D.
Co-PIs, Collaborative Math
SRI International
333 Ravenswood Ave BS 190
Menlo Park, CA 94025
Phone: 650-859-4518
erika.gaylor@sri.com
Collaborative Math
Creating Sustainable Excellence in Mathematics for Head Start Programs
Teacher Consent Form

I have been fully informed as to the purpose and procedure of this study (2016-2018), which includes the following elements:
• Assessment of children in my classroom;
• Completion of on-line surveys;
• and video recording of my teaching math.

Remember: All information is confidential and only research staff will have access to videos and data.

In signing this form, I verify that the box checked below expresses my wishes regarding my consent to participate or not participate in this study.

☐ Yes, I agree to participate.  ☐ No, I do not agree to participate.

☐ Yes, I agree that field notes and logs created during PD activities may be reviewed by researchers on this project. Identifiers will not be included in any publications, presentations or journals.

My name (print)

My signature  Date

Head Start Center Name  School/class phone

Work e-mail  Classroom

Please print, sign, and return to our Data Coordinator, Suzanne Budak, at Erikson Institute: E-mail (as a PDF file): collaborativemath@erikson.edu  Fax: (312) 755-0928
APPENDIX C

ATTITUDES, BELIEFS, AND CONFIDENCE IN PRESCHOOL MATH (ABC-PM)
Directions: This section of the survey asks about what you believe about math and teaching math to young children. Please mark how much you agree or disagree with the statements below.

Choices: Strongly Disagree  Disagree  Neutral  Agree  Strongly Agree

Questions:
Confidence in Math Teaching
1. I am skilled at evaluating my students’ math learning.
2. I easily can use math assessment results to guide my lesson planning.
3. Setting appropriate math learning goals for my students is easy for me.
4. I am good at anticipating when my students might be confused with a certain math concept.
5. Engaging students in math thinking is easy for me.
6. I am good at encouraging students to represent math in a variety of ways (such as drawings, manipulatives, symbols, and language).
7. I am skilled at connecting math learning to other curricular areas.
8. It is easy for me to help students explain their thinking about math.
9. Preparing engaging math experiences for my students is one thing I am good at doing.
10. I am skilled at furthering my students’ math knowledge when they make math comments or discoveries
11. Using assessment results to set math goals does not come easy to me for some students.*
12. It is not easy for me to engage some students in math learning. *
13. I struggle to help some students communicate their thinking about math. *
14. I find it difficult to help students see connections between their play and underlying math concepts. *
15. Some math concepts are difficult for me to teach. *
16. I find it challenging to adapt math activities for students who are more or less advanced than their peers. *

Positive Math Attitudes
17. I am not a "math person." *
18. I have a hard time quickly calculating arithmetic facts in my head. *
19. I can easily convert fractions into percentages or decimal numbers.
20. I'm good at looking at numeric data and finding patterns.
21. Math was one of my best subjects in school.
22. I am not good at math puzzles. *
23. Just the word "math" can make me feel nervous. *
24. I can easily figure out how something would look from another angle.
25. I'm good at estimating the height of objects.
26. Estimating the distance between two locations is easy for me.

*these items are reverse coded
APPENDIX D

PEDAGOGICAL CONTENT KNOWLEDGE IN PRESCHOOL MATHEMATICS (PM-PCK)
Please read through Scene One, looking for math. You can read through it as many times as you want.

Scene One
Brittany and Jacob are playing in the dramatic play area and want to put their 5 babies to bed. There are no doll beds, so they make “cribs” out of three shoeboxes. Jacob says “but there aren’t enough cribs.” Brittany responds, “these babies are younger” picking out the three babies with no hair and setting them near the shoeboxes. She picks up the two babies with thick hair, says “these babies don’t need to nap anymore,” and sets them aside. Jacob says “OK, but this baby needs the most room” and puts the biggest bald baby in the biggest shoebox. Brittany watches him and then puts the medium-sized bald baby in the medium-sized shoebox and the smallest bald baby in the smallest shoebox. Jacob says “now go to sleep, babies.”

When you are through reading, please go on to the next page.
In the table below, please **list as many examples of math** as you can find in Scene One, one example in each row. Some people see only one example, and some see more. Then, next to each example, please **explain how that example is mathematical**, and tell us **what kind of math** it shows. You can go back to the Scene and read it again if you like.

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<thead>
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<th></th>
<th>Where do you see any math in this play? What part of the children’s play has math in it?</th>
<th>How is that mathematical?</th>
<th>What kind of math is it? (check all that apply)</th>
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When you are done, please go on to the second Scene.
Please read through Scene Two, looking for math. You can read through it as many times as you want.

Scene Two

Brandon and Tyra are playing with unit blocks and want to build a cage for a mama elephant and her two babies. Tyra builds the first two sides of the cage, set up at a right angle to each other, and using two unit blocks for each side. Brandon sets up the third cage side, but uses one unit block and a half unit block instead of two full units. When Brandon tries to finish the cage by building the 4th side, he sees that it doesn’t hit the 1st side exactly at the corner. He says, “hey, it doesn’t work...I’ll fix it.” He adds another half unit block to his 3rd side and he and Tyra finish the cage together. Tyra and Brandon place the three elephants inside.

When you are through reading, please go on to the next page.
In the table below, please list as many examples of math as you can find in Scene Two, one example in each row. Some people see only one example, and some see more. Then, next to each example, please explain how that example is mathematical, and tell us what kind of math it shows. You can go back to the Scene and read it again if you like.

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</table>

Thanks for completing our survey!
APPENDIX E

EVALUATING QUALITY INTERACTIONS IN PRESCHOOL – MATH (EQUIP-M)
The purpose of EQUIP-M is to measure quality of instruction during an episode when a teacher plans to interact with children around math. EQUIP-M is predicated upon two assumptions: that instructional opportunities for preschool math are embedded in routines, games, play, books, blocks, etc.; and that the mathematical quality of instruction can be assessed by examining the interactions between teacher and students around the mathematics, as illustrated in the instructional triangle below.

![Instructional Triangle](image)

Specifically, EQUIP-M focuses on three interactions, those between the teacher and the mathematics (Teacher Intentionality), the teacher and the students around the mathematics (Teacher Responsiveness), and students and the mathematics (Student Mathematical Sense-making). Interactions between teachers and students that are more general in nature, such as behavior management, are not within the scope of this tool, and are more appropriate for other observation tools, such as the CLASS.

These three broad domains of classroom interactions are furthered divided into eight dimensions of quality. These dimensions are:

**Teacher Intentionality**
- Teacher Provides Context for Mathematics Learning
- Teacher Activates Students’ Engagement in the Mathematics
- Teacher Uses Mathematical Language to Promote Concept Development

**Teacher Responsiveness**
- Teacher Looks for Evidence of Understanding
- Teacher Uses Student Contributions to Socially Construct Math Learning
- Teacher Clarifies Student Mistakes to Promote Concept Development

**Student Mathematical Sense-Making**
- Students Communicate Their Thinking About Mathematics to Others
- Students Display Learning-Related Behaviors

**Scoring Procedures**
Each dimension is scored on a 4-point scale that describes the degree to which evidence of high-quality interactions are observed during a teacher-led activity. Dimensions within the Teacher Intentionality, Teacher Responsiveness, and Student Mathematical Sense-Making domains are scored based on quality and frequency, to a lesser extent. An interaction can
receive a high score even if the target behaviors occurs in only a portion of the interaction. Below is a general example of the scoring rubric. Each rubric is individualized for its corresponding dimension.

<table>
<thead>
<tr>
<th>Not Present</th>
<th>Low</th>
<th>Mid</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>No evidence of the indicator was observed. OR Features related to the dimension detract from the mathematics of the activity.</td>
<td>Minimal evidence of the indicators were observed.</td>
<td>Mid-range as well as mixed, or inconsistent, evidence of the indicators were observed.</td>
<td>High level of evidence of the indicators were observed. The indicators were characteristic of the activity.</td>
</tr>
</tbody>
</table>
APPENDIX F

GROUP COACHING LOG
<table>
<thead>
<tr>
<th>Preparing to Conduct Activity</th>
<th>T1:</th>
<th>T2:</th>
<th>T3:</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>What Big Ideas do we want children to have a chance to wrestle with during this activity?</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>What TSG objectives might be observed during this activity?</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>What will we look for to tell if Big Ideas-thinking is activated in the children? (Anticipate Student Responses)</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>What could we do/say to help activate Big Ideas-thinking?</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Question</td>
<td>T1:</td>
<td>T2:</td>
<td>T3:</td>
</tr>
<tr>
<td>-------------------------------------------------------------------------</td>
<td>-----------------------------</td>
<td>-----------------------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>Which teacher interactions will we use during this activity to activate the Big Ideas?</td>
<td>T1:</td>
<td>T2:</td>
<td>T3:</td>
</tr>
<tr>
<td>Logistics Planning</td>
<td>T1:</td>
<td>T2:</td>
<td>T3:</td>
</tr>
<tr>
<td>Who will be responsible for prepping and managing the materials for the activity?</td>
<td>T1:</td>
<td>T2:</td>
<td>T3:</td>
</tr>
<tr>
<td>Who will be responsible for managing the flow of the children while the activity is being facilitated? How?</td>
<td>T1:</td>
<td>T2:</td>
<td>T3:</td>
</tr>
<tr>
<td>In what order will the teachers try out the activity?</td>
<td>T1:</td>
<td>T2:</td>
<td>T3:</td>
</tr>
<tr>
<td>Which teachers are/are not okay with the coach stepping in to provide live coaching?</td>
<td>T1:</td>
<td>T2:</td>
<td>T3:</td>
</tr>
<tr>
<td><strong>LET'S PRACTICE!</strong></td>
<td>T1:</td>
<td>T2:</td>
<td>T3:</td>
</tr>
<tr>
<td>Who practiced the activity?</td>
<td>T1:</td>
<td>T2:</td>
<td>T3:</td>
</tr>
<tr>
<td>Reflecting</td>
<td>T1:</td>
<td>T2:</td>
<td>T3:</td>
</tr>
<tr>
<td>---------------------------------------------------------------------------</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
</tr>
<tr>
<td>Based on the identified plan for Big Ideas and Teacher Interactions,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>how do the teachers think the activity went? Why?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Which interactions did the teachers identify that they engaged in that</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>helped the kids think about the math?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>What changes might the teaching team make to how they conducted the</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>activity that will help make the Big Ideas clearer for the children?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Projecting Forward</td>
<td>T1:</td>
<td>T2:</td>
<td>T3:</td>
</tr>
<tr>
<td>--------------------</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
</tr>
<tr>
<td>How will the teaching team continue/build on the activity?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>What interactions does each teacher want to work on going forward?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>How will the teachers support each other in improving their practice as they continue this activity?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>How will the teaching team inform parents about the Big Ideas that were explored during this activity?</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX G

INSTRUCTIONAL LEADER CONSULTATION AROUND GROUP COACHING LOG
### PREPARING FOR THE PLANNING CONVERSATION

<table>
<thead>
<tr>
<th>Question</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>What did the teaching staff think about the Professional Development lab they recently attended?</td>
<td></td>
</tr>
<tr>
<td>What new techniques and/or ideas are the teachers discussing among themselves since the lab?</td>
<td></td>
</tr>
<tr>
<td>What does the Instructional Leader identify as the Big Ideas that this activity will activate for students?</td>
<td></td>
</tr>
<tr>
<td><strong>Has the Instructional Leader heard any misgivings or excitement about conducting this activity?</strong></td>
<td></td>
</tr>
<tr>
<td>-------------------------------------------------</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>How well does the teaching team to be coached...</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Work together?</td>
</tr>
<tr>
<td>• Receive feedback?</td>
</tr>
<tr>
<td>• Plan activities?</td>
</tr>
</tbody>
</table>

**What concerns does the instructional leader have about each Teaching Team to be coached?**

<table>
<thead>
<tr>
<th><strong>What role does the Instructional Leader want to take during the Planning conversation?</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Observer? Co-facilitator? Sole facilitator? (Has this role changed from the previous cycle?)</td>
</tr>
</tbody>
</table>
What plans has the Instructional Leader made to protect the time for the observation and reflection the following day? How likely is it that s/he will be able to complete the cycle with this team?

**IL Reflection on the Power of Planning:**

How was this conversation useful to you? What new ideas/topics did you receive from the experience?
DEBRIEFING THE PLANNING CONVERSATION

<table>
<thead>
<tr>
<th>How well did the Instructional Leader think the session went with the teaching team? Examples?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>What coach moves did the Instructional Leader see the coach make? How effective were those coach moves?</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Were any of the coach moves less familiar to the Instructional Leader? How could the Instructional Leader imagine incorporating them into his/her own practice of supporting teachers' instruction?</td>
</tr>
</tbody>
</table>

| How was this conversation useful to you? What new ideas/topics did you receive from the experience? |
### PREPARING FOR THE REFLECTING CONVERSATION

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>How did the activities turn out when each member of the team had their turn being the facilitator?</td>
<td></td>
</tr>
<tr>
<td>What points should be brought up during the reflecting conversation?</td>
<td></td>
</tr>
<tr>
<td>Question</td>
<td>Answer</td>
</tr>
<tr>
<td>-------------------------------------------------------------------------</td>
<td>--------</td>
</tr>
<tr>
<td>How will the data be shared with the team?</td>
<td></td>
</tr>
<tr>
<td>What role will the Instructional leader have during the reflecting conversation? Observer? Co-facilitator? Sole facilitator?</td>
<td></td>
</tr>
<tr>
<td>What did the Instructional Leader learn from this conversation?</td>
<td></td>
</tr>
</tbody>
</table>
### DEBRIEFING THE REFLECTING CONVERSATION

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>What did you notice about how each member of the team reflected on their turn to lead the activity?</td>
<td></td>
</tr>
<tr>
<td>How likely is it that members of this team will incorporate the feedback they received into their practice? Why or why not?</td>
<td></td>
</tr>
<tr>
<td>Question</td>
<td>Answer</td>
</tr>
<tr>
<td>-------------------------------------------------------------------------</td>
<td>--------</td>
</tr>
<tr>
<td>What kind of supportive actions will help this team be successful in incorporating the feedback from today?</td>
<td></td>
</tr>
<tr>
<td>How and when can these supportive actions be put into place.</td>
<td></td>
</tr>
<tr>
<td>What moves did the coach make during the Reflecting Conversation and how effective were they?</td>
<td></td>
</tr>
<tr>
<td>How can the Instructional Leader imagine incorporating these coach moves into their own practice of supporting teachers’ instruction?</td>
<td></td>
</tr>
<tr>
<td>What did the Instructional Leader learn from this conversation?</td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX H

COACHING FIDELITY SURVEY
Existing Data

### Part 1: Planning Conversation

**DATE:** ___________________

1. Did this Conversation occur? (shade box)  
   □ No  □ Yes  
   If no, go to Q16 and record reason.

2. Was this group coaching session rescheduled? (shade box)  
   □ No  □ Yes  
   If yes, what was the reason for the session being rescheduled?

**Directions:** If you answer YES to Question 3 continue answering the questions for that individual across the table. Answer No or N/A to Question 3, then skip to Question 6.

<table>
<thead>
<tr>
<th></th>
<th>3. Was the individual present during the planning conversation?</th>
<th>4. Was this individual present during the entire planning session from beginning to end?</th>
<th>5. If this individual was not present during the entire session, how long were they there?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher 1</td>
<td>□ Yes  □ No</td>
<td>□ Yes  or  □ No</td>
<td>____ minutes</td>
</tr>
<tr>
<td>Teacher 2</td>
<td>□ Yes  □ No  □ N/A</td>
<td>□ Yes  or  □ No</td>
<td>____ minutes</td>
</tr>
<tr>
<td>Teacher 3</td>
<td>□ Yes  □ No  □ N/A</td>
<td>□ Yes  or  □ No</td>
<td>____ minutes</td>
</tr>
<tr>
<td>Instructional Leader 1</td>
<td>□ Yes  □ No</td>
<td>□ Yes  or  □ No</td>
<td>____ minutes</td>
</tr>
<tr>
<td>Instructional Leader 2</td>
<td>□ Yes  □ No  □ N/A</td>
<td>□ Yes  or  □ No</td>
<td>____ minutes</td>
</tr>
<tr>
<td>Other Person</td>
<td>□ Yes  □ No  □ N/A</td>
<td>□ Yes  or  □ No</td>
<td>____ minutes</td>
</tr>
</tbody>
</table>

6. If present, what role did the Primary Instructional Leader have in the session? (shade box)  
   □ Not Present  □ Observer  □ Co-facilitator  □ Sole-facilitator

7. How long did the meeting last (in minutes): ____ minutes

8. Where did the conversation take place? (shade box)  
   □ In classroom  □ Outside of classroom  □ Both

9. How many times was the meeting disrupted? (shade box)  
   □ None or 1 time  □ 2 times  □ 3 times  □ Many times

10. Overall, how much of the conversation was conducted in Spanish? (shade box)
11. Were materials present for practice? (shade box) □ YES □ NO

12. Which teachers practiced the activity? (circle response)

<table>
<thead>
<tr>
<th>Teacher 1</th>
<th>Teacher 2</th>
<th>Teacher 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>□ No</td>
<td>□ Yes</td>
<td>□ No</td>
</tr>
<tr>
<td>□ No</td>
<td>□ Yes</td>
<td>□ No</td>
</tr>
<tr>
<td>□ No</td>
<td>□ Yes</td>
<td>□ No</td>
</tr>
</tbody>
</table>

13. How engaged was the teacher in planning the activity during this session? (circle response)

1 = distracted/unprepared; 4 = fully participated/fully prepared

<table>
<thead>
<tr>
<th>Teacher 1</th>
<th>Teacher 2</th>
<th>Teacher 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 2 3 4</td>
<td>1 2 3 4</td>
<td>1 2 3 4</td>
</tr>
</tbody>
</table>

14. Who took responsibility for planning the activity? (circle response)

<table>
<thead>
<tr>
<th>Coach took full responsibility</th>
<th>Coach and teaching team contributed equally</th>
<th>The teaching team took full responsibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 2 3 4</td>
<td>1 2 3 4</td>
<td>1 2 3 4</td>
</tr>
</tbody>
</table>

15. How receptive was the teaching team to the coach’s observations and suggestions? (circle response)

1 = defensive; 4 = thoughtfully processes feedback and how to incorporate into practice

<table>
<thead>
<tr>
<th>Teacher 1</th>
<th>Teacher 2</th>
<th>Teacher 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 2 3 4</td>
<td>1 2 3 4</td>
<td>1 2 3 4</td>
</tr>
</tbody>
</table>

16. How well did the teaching team understand the Big Idea? (circle response)

1 = can’t name BI; 4 = names BI and can provide example

<table>
<thead>
<tr>
<th>Teacher 1</th>
<th>Teacher 2</th>
<th>Teacher 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 2 3 4</td>
<td>1 2 3 4</td>
<td>1 2 3 4</td>
</tr>
</tbody>
</table>

17. On a scale from 1 (very poor) to 5 (excellent), please rate your level of rapport with the teaching team. (circle response)

<table>
<thead>
<tr>
<th>Teacher 1</th>
<th>Teacher 2</th>
<th>Teacher 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
</tbody>
</table>

18. Please record additional information here (e.g., explanations for responses to the questions above, additional notes). Optional
Part 2: Observation

DATE: ______________________

1. Did this Observation occur? (shade box) □ No □ Yes
   If no, go to Q9 and record reason.

2. Was this observation rescheduled? (shade box) □ No □ Yes
   If yes, what was the reason for the observation being rescheduled?

Directions: If you answer YES to Question 3 continue answering the questions for that individual across the table. Answer No or N/A to Question 3, then skip to Question 6.

<table>
<thead>
<tr>
<th></th>
<th>3. Was the individual present during observation?</th>
<th>4. Was this individual present during the entire observation session from beginning to end?</th>
<th>5. If this individual was not present during the entire session, how long were they there?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher 1</td>
<td>□ Yes □ No</td>
<td>□ Yes □ No</td>
<td>___ minutes</td>
</tr>
<tr>
<td>Teacher 2</td>
<td>□ Yes □ No □ N/A</td>
<td>□ Yes □ No</td>
<td>___ minutes</td>
</tr>
<tr>
<td>Teacher 3</td>
<td>□ Yes □ No □ N/A</td>
<td>□ Yes □ No</td>
<td>___ minutes</td>
</tr>
<tr>
<td>Instructional Leader 1</td>
<td>□ Yes □ No</td>
<td>□ Yes □ No</td>
<td>___ minutes</td>
</tr>
<tr>
<td>Instructional Leader 2</td>
<td>□ Yes □ No □ N/A</td>
<td>□ Yes □ No</td>
<td>___ minutes</td>
</tr>
<tr>
<td>Other Person</td>
<td>□ Yes □ No □ N/A</td>
<td>□ Yes □ No</td>
<td>___ minutes</td>
</tr>
</tbody>
</table>

6. How long did the observation last (in minutes): ___ minutes

7. How many times was the observation disrupted? (shade box)
   □ None or 1 time □ 2 times □ 3 times □ Many times

8. Overall, how much of the math activity was conducted in Spanish? (shade box)
   □ None □ A little (a few words/sentences) □ More than a little but less than half
   □ More than half but not the whole conversation □ Whole conversation

9. Which teachers were observed trying out the activity? (circle response)
<table>
<thead>
<tr>
<th>Teacher 1</th>
<th>Teacher 2</th>
<th>Teacher 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>□ No</td>
<td>□ Yes</td>
<td>□ No □ Yes</td>
</tr>
<tr>
<td>□ No □ Yes</td>
<td>□ Yes</td>
<td>□ No □ Yes</td>
</tr>
</tbody>
</table>
10. On a scale from 1 (not well at all) to 5 (very well), how well did the teaching team integrate the Big Ideas into their interactions? (Please refer to Preparing to Conduct the Activity section of the Planning Log and the Teacher Tally Sheet when making this judgment)

<table>
<thead>
<tr>
<th>Teacher 1</th>
<th>Teacher 2</th>
<th>Teacher 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

11. Please record additional information here (e.g., explanations for responses to the questions above, additional notes). \textit{Optional}
Part 3: Reflecting Conversation

1. Did this Conversation occur? (shade box)  
   □ No □ Yes
   If no, go to Q13 and record reason.

2. Was this group coaching session rescheduled? (shade box)  
   □ No □ Yes
   If yes, what was the reason for the session being rescheduled?

   Directions: If you answer YES to Question 3 continue answering the questions for that individual across the table. Answer No or N/A to Question 3, then skip to Question 6.

<table>
<thead>
<tr>
<th></th>
<th>3. Was the individual present during the reflecting conversation?</th>
<th>4. Was this individual present during the entire reflecting conversation from beginning to end?</th>
<th>5. If this individual was not present during the entire session, how long were they there?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher 1</td>
<td>□ Yes □ No</td>
<td>□ Yes or □ No</td>
<td>___ minutes</td>
</tr>
<tr>
<td>Teacher 2</td>
<td>□ Yes □ No □ N/A</td>
<td>□ Yes or □ No</td>
<td>___ minutes</td>
</tr>
<tr>
<td>Teacher 3</td>
<td>□ Yes □ No □ N/A</td>
<td>□ Yes or □ No</td>
<td>___ minutes</td>
</tr>
<tr>
<td>Instructional Leader 1</td>
<td>□ Yes □ No</td>
<td>□ Yes or □ No</td>
<td>___ minutes</td>
</tr>
<tr>
<td>Instructional Leader 2</td>
<td>□ Yes □ No □ N/A</td>
<td>□ Yes or □ No</td>
<td>___ minutes</td>
</tr>
<tr>
<td>Other Person</td>
<td>□ Yes □ No □ N/A</td>
<td>□ Yes or □ No</td>
<td>___ minutes</td>
</tr>
</tbody>
</table>

6. If present, what role did the Primary Instructional Leader have in the session? (shade box)  
   □ Not Present □ Observer □ Co-facilitator □ Sole-facilitator

7. How long did the meeting last (in minutes): ___ minutes

8. Where did the conversation take place? (shade box)  
   □ In classroom □ Outside of classroom □ Both

9. How many times was the meeting disrupted? (shade box)  
   □ None or 1 time □ 2 times □ 3 times □ Many times

10. Overall, how much of the conversation was conducted in Spanish? (shade box)  
    □ None □ A little (a few words/sentences) □ More than a little but less than half
More than half but not the whole conversation  

11. How engaged was the teacher in critically analyzing their practice during this session? (circle response)
   1 = distracted/unprepared; 4 = fully participated/fully prepared

<table>
<thead>
<tr>
<th>Teacher 1</th>
<th>Teacher 2</th>
<th>Teacher 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 2 3 4</td>
<td>1 2 3 4</td>
<td>1 2 3 4</td>
</tr>
</tbody>
</table>

12. How receptive was the teaching team to the coach’s observations and suggestions? (circle response)
   1 = defensive; 4 = thoughtfully processes feedback and how to incorporate into practice

<table>
<thead>
<tr>
<th>Teacher 1</th>
<th>Teacher 2</th>
<th>Teacher 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 2 3 4</td>
<td>1 2 3 4</td>
<td>1 2 3 4</td>
</tr>
</tbody>
</table>

13. Who took responsibility for developing a plan for projecting forward? (circle response)

<table>
<thead>
<tr>
<th>Coach took full responsibility</th>
<th>Coach and teaching team contributed equally</th>
<th>The teaching team took full responsibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>5</td>
</tr>
</tbody>
</table>

14. On a scale from 1 (very poor) to 5 (excellent), please rate your level of rapport with the teaching team. (circle response)

<table>
<thead>
<tr>
<th>Teacher 1</th>
<th>Teacher 2</th>
<th>Teacher 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
</tr>
</tbody>
</table>

15. Please record additional information here (e.g., explanations for responses to the questions above, additional notes). Optional
APPENDIX I

SUCCESSES AND CHALLENGES SURVEY – TEACHERS
Questions related to group coaching from the larger survey

4. [OPEN ENDED] How would you describe your relationship with your Collaborative Math coach?

5. [OPEN ENDED] How did coaching influence your team’s math teaching? Please describe the skills and knowledge that you and your team gained through coaching.

6. [OPEN ENDED] What were the benefits and limitations of being coached with your colleagues?

7. [OPEN ENDED] How would you describe your role in planning for and reflecting on math activities during coaching? How would you describe your coach’s role?

8. [OPEN ENDED] What were the benefits and limitations of having your instructional leader sit in on a coaching session?

9. [OPEN ENDED] What suggestions for improvement would you offer Collaborative Math coaches?

Questions related to learning labs from the larger survey.

1. [OPEN ENDED] Which learning lab experience had the greatest impact on your day-to-day work in the classroom? How so?

2. [OPEN ENDED] What were the biggest challenges in applying what you learned about in learning labs to your work in the classroom? What do you think could help to overcome those challenges?

3. [OPEN ENDED] What do you think are the most important ideas that preschoolers need to understand about number sense? How would you have answered this before participating in the Collaborative Math Learning Labs?
APPENDIX J

TEACHER BACKGROUND AND DEMOGRAPHICS SURVEY
1. What is your job title?

2. How many classrooms do you teach/assist?

3. What are your responsibilities during a typical day at the center?

4. How many years have you worked at your current site?

5. How many total years of experience do you have working with young children in formal settings (such as family child care home, preschool, Head Start, center-based care)?

6. What types of settings have you worked in? (Check all that apply)

   - Family child care home
   - Child care center (not Head Start)
   - Part-day preschool
   - Before/after school program
   - Elementary school
   - Other (please specify)

7. About how many hours of math professional development education workshops have you taken in the last year? [open response]

8. What is your gender?

   - Female
   - Male
   - Prefer not to answer

9. What is your ethnicity? (Check all that apply)

   - American Indian or Alaskan Native
   - Asian or Pacific Islander
   - Black or African American
   - Hispanic or Latino
   - White/ Caucasian
   - Prefer not to answer
   - Other (please specify)

10. What is the highest level of school you have completed?

    - Less than high school degree
    - High School degree or equivalent (e.g., GED)
☐ Some college but no degree
☐ Associate degree
☐ Bachelor degree
☐ Graduate degree

11. Do you have any teaching licenses, endorsements, credentials or certificates? (Check all that apply)
☐ Child Development Associate (CDA) Credential
☐ Professional Educator License
☐ Early Childhood Education Endorsement (birth - grade 3)
☐ Elementary Education Endorsement
☐ Special Education Endorsement
☐ Bilingual/ ELL Endorsement
☐ None
☐ Other (please specify)

12. Which language(s) do you speak? (Check all that apply)
☐ English
☐ Spanish
☐ Other (please specify)

13. Which language do you speak most fluently? (Select one)
☐ English
☐ Spanish
☐ Other (please specify)

14. Which language(s) do you use when interacting with the children in your classroom and their families around math? (Select one)
☐ English only
☐ Spanish only
☐ English and Spanish
☐ Other (please specify)
APPENDIX K

SUCCESSES AND CHALLENGES SURVEY – COACHES
The following questions ask you to think about your work with *Collaborative Math* during 2016-2017 (the first year of the project). Please think about only this project as you answer.

[All questions are open-ended response. Questions 1-6 Mirror Questions from the Success and Challenges Teacher Survey]

1. How would you describe your relationship with your *Collaborative Math* teachers?
2. How did coaching influence your teachers’ math teaching? Please describe the skills and knowledge that you think your teachers gained through coaching.
3. What were the benefits and limitations of coaching teachers as a group?
4. How would you describe your teachers’ roles in planning for and reflecting on math activities during coaching? How would you describe your role?
5. What were the benefits and limitations of having the instructional leader sit in on a coaching session?
6. How do you hope to improve your coaching in the future?
7. What do you think is needed in order for these improvements to occur?
8. How would you describe the *Collaborative Math* coaching model to someone unfamiliar with the project?
9. How would you describe your role as a coach? What do you do?
10. What strategies do you use when working with teachers?
11. What would you say is the focus or main goal of *Collaborative Math* coaching?
12. Sometimes coaching can be highly reflective with less input from the coach and more thinking contributed by the teacher. Other times it can be more directive, with coaches offering concrete feedback. How would you describe the coaching you do as part of *Collaborative Math*?
13. Please describe how you use the coaching forms provided by *Collaborative Math*.
14. Do you share the forms with teachers or instructional leaders? If yes, please explain.
15. Please use this space to share any other thoughts about *Collaborative Math* coaching.
APPENDIX L

COACH CHARACTERISTICS SURVEY
1. How many years have you worked as a coach with the Erikson Early Math Collaborative? [Open Response]

2. On a scale of 1-5, how would you rate your math content knowledge before you began working with EMC? (5 being extremely strong and 1 being extremely weak)
   
   2a. How would you rate yourself currently?

3. On a scale of 1-5, how would you rate your ability to teach preschool math before you began working with EMC? (5 being extremely strong and 1 being extremely weak)
   
   3a How would you rate yourself currently?

4. On a scale of 1-5, how would you rate your math confidence before you began working with EMC? (5 being extremely strong and 1 being extremely weak)
   
   4a. How would you rate yourself currently?

5. On a scale of 1-5, how would you rate your skills as a coach before you began working with EMC?

   5a. How would you rate yourself currently?

6. How many total years and months have you worked as a coach, including in organizations other than the Early Math Collaborative? [Short Response: Years___ Months___]

7. What types of settings have you worked in as a coach, including in organizations other than the Early Math Collaborative?
   
   □ Family child care home
   □ Child care center (not Head Start)
   □ Head Start
   □ Preschool
   □ Elementary school
   □ Other (please specify)

8. How many years and months of experience do you have as a classroom teacher working directly with children? [Short Response: Years___ Months___]

9. Which grades have you taught? (check all that apply)
   
   □ Infants
   □ Toddlers
   □ PreK (3-4 year olds)
   □ K
   □ 1
   □ 2
   □ 3
10. What types of settings have you worked in as a teacher? (Check all that apply)

- Family child care home
- Child care center (not Head Start)
- Head Start
- Preschool
- Elementary school
- Other (please specify)

11. Please list all degrees earned (include type and subject area. For example, “BA in Elementary Education and MA in Child Development”) [Open Response]

12. Do you have any teaching licenses, endorsements, credentials or certificates? (Check all that apply)

- Child Development Associate (CDA) Credential
- Professional Educator License
- Early Childhood Education Endorsement (birth - grade 3)
- Elementary Education Endorsement
- Special Education Endorsement
- Bilingual/ ELL Endorsement
- None
- Other (please specify)

13. How have you been supported in your work as an early math coach? [Open Response]

14. Outside of the Early Math Collaborative, have you been a part of any other trainings that have been applicable to your coaching work?

- Yes (please explain) [Open Response]
- No

15. What is your ethnicity? (Check all that apply)

- American Indian or Alaskan Native
- Asian or Pacific Islander
- Black or African American
16. Which language(s) do you speak? (Check all that apply)
   - English
   - Spanish
   - Other (please specify)

17. Which language do you speak most fluently? (Select one)
   - English
   - Spanish
   - Other (please specify)

18. What is your gender identity?
   - Male
   - Female
   - Other
APPENDIX M

COACH CONSENT FORM
Dear Coach:

I would like to invite you to participate in a research study during Fall 2018. I am a doctoral student at Erikson Institute and Loyola University Chicago. As an extension of the Collaborative Math in Head Start study I plan to investigate how math-focused coaching impacts preschool teachers’ content knowledge, teaching practice, and dispositions (attitudes, beliefs, and confidence). I am interested in learning more about the math coaching model and factors that influence the coaching process. I am inviting you to participate because you were a coach as part of Collaborative Math in 2016-2017.

Your participation in the research study is voluntary. If you agree to participate, you will be asked to complete two online surveys.

Procedure. In agreeing to participate, you consent to:

• Complete a 45-minute online survey about your experience coaching teachers as part of Collaborative Math. Questions will ask about the coaching model, successes and challenges, your relationships with teachers, and your goals for future coaching.
• Complete a 15-minute online survey about your background, including teaching and coaching experience, degrees, languages spoken, and race/ethnicity.
• You will receive a stipend of a $40 gift card for your time electronically after completion of surveys.

To complete the online surveys, you will receive an e-mail that provides you with an ID number and a link to the survey website.

Voluntary Participation. Your agreement to participate is entirely voluntary. At any time for any reason, you can decide not to participate in the study. Participation or declining to participate will have no effect on your employment with Erikson Institute. Coach colleagues, supervisors, and other Erikson staff will not be told your decision.

Risks and Discomforts. I do not foresee any risks and only minimal inconveniences as a result of participating in this study. Questions on surveys are similar to those asked as part of normal work experiences and reflective meetings. You may skip any questions on the survey that you do not wish to answer.

Benefits. You may benefit professionally from the opportunity to reflect on your coaching and its impact. Your participation will also help us advance the knowledge of teacher professional development for early math.

Confidentiality. I will never include names or other identifying information about you, your teachers, or your sites in any reports, publications, or presentations of this research. Answers
from the two surveys will be analyzed separately in order to avoid accidentally identifying you based on your background information. Access to survey data is limited to myself and a research assistant. Consent forms will be stored in a locked cabinet at Erikson and destroyed three years from the end of the study.

**Contact Persons.** If you have any questions about this study now or at any time, you can contact me at l.solarski@erikson.edu or (630) 484-6374. You may also contact my advisor, Dr. Gillian McNamee, at (312) 893-7135 or GMcNamee@erikson.edu, or my committee member, Dr. Jennifer McCray at (312) 893-7249 or JMcCray@erikson.edu. In the event that you believe you have suffered any physical or psychological injury as a result of participation in the research program, you may contact the Chairperson of the Erikson Institute Institutional Review Board for the Protection of Human Subjects, Dr. Amanda Moreno (312) 755-2250.

*Please complete the form below, check a box to indicate whether you consent, and return the form.*

Sincerely,

Lauren Solarski, MS
Coach Consent Form

I have been fully informed as to the purpose and procedure of this study, which includes the following elements:

- Completion of two online surveys

In signing this form, I verify that the box checked below expresses my wishes regarding my consent to participate or not participate in this study.

☐ Yes, I agree to participate
☐ No, I do not agree to participate.

My name (print)

My signature ___________________________ Date

Preferred e-mail ___________________________

Please print, sign, and return to Lauren in person or electronically.

E-mail (as a PDF file): L.Solarski@erikson.edu
APPENDIX N

CODEBOOKS
<table>
<thead>
<tr>
<th>Code Title</th>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>answer questions</td>
<td>Teacher mentions a coach answers questions, or protocol has coach ask if there are any questions. Closely related to direct feedback, but actively sought by teacher.</td>
<td>&quot;always ready to offer suggestions and answer our questions.&quot;</td>
</tr>
<tr>
<td>build upon existing / personalize</td>
<td>Coach seeks information about what is already happening in a classroom or center and establishes connections to expand upon it (as opposed to adding something completely new). For example, asking about how the CM lesson connects to the Teaching Strategies Gold curriculum.</td>
<td>&quot;The coach would give us an assignment with something room to make it ours, then we would implement in the way the fit our classroom best.&quot; &quot;Weave into their daily routines&quot;</td>
</tr>
<tr>
<td>children</td>
<td>Lesson planning considers children’s developmental levels, including references to age or prior demonstrated knowledge, teachers anticipate children’s responses, &quot;kid watching&quot;.</td>
<td>&quot;developmentally appropriate&quot;, &quot;targeted for age levels&quot;, &quot;kid watching&quot;</td>
</tr>
<tr>
<td>coach as teacher</td>
<td>Participant uses the word &quot;teach&quot; or &quot;taught&quot; or other school-related words to describe what the coach does.</td>
<td>&quot;the coach would give us an assignment&quot;</td>
</tr>
<tr>
<td>coach the leader</td>
<td>Reference to the coach working with an Instructional Leader (sometimes referred to as Director)</td>
<td>&quot;the instructional leader becomes part of the common conversation that the teachers are creating which, I believe, builds more of a learning community.&quot;</td>
</tr>
<tr>
<td>contact outside meetings</td>
<td>Coach corresponds with teacher outside of scheduled visits: reach out, e-mail questions.</td>
<td>&quot;went that extra mile answering questions through emails and calls until we knew that it was coming altogether. She WAS EXTRA SUPPORTIVE. :)</td>
</tr>
<tr>
<td>data</td>
<td>Coach gathers evidence of student learning to discuss with teacher, uses observation sheet, checklist, take notes, script</td>
<td>&quot;Using the notes taken during the lesson, we then look at points during which the big idea could’ve been addressed differently during the lesson and then other things that can be done to build on some of those ideas.&quot;</td>
</tr>
<tr>
<td>direct feedback</td>
<td>Coach directly tells the teacher &quot;suggestions&quot;, &quot;advice&quot;, &quot;tips&quot;, compliance, accountability</td>
<td>&quot;point out successful moments&quot; &quot;clear up misconceptions&quot;</td>
</tr>
<tr>
<td>families</td>
<td>The coach discusses a larger CM intervention component that is intended to encourage families to participate in their child’s mathematical learning</td>
<td>&quot;my instructional leader planned parent activity nights that helped parents understand what the kids were learning in the classroom.&quot;</td>
</tr>
<tr>
<td>games or activity</td>
<td>Participants discuss a specific game or activity as part of planning: sorting station, hoop game, dot card transition</td>
<td>&quot;They also were able to carry out the dot card routine with thoughtful use of the dot cards.&quot; - Coach 24</td>
</tr>
<tr>
<td>goal</td>
<td>Participant mentions a goal of coaching.</td>
<td>&quot;makes sure center do what they committed to” &quot;help teachers have better mathematical understanding&quot;</td>
</tr>
<tr>
<td>guiding philosophy</td>
<td>Direct reference to or description of model from the literature: instructional coaching (partnership), content coaching, (pedagogical content knowledge), cognitive coaching (reflection and autonomy), differentiated coaching (individual teacher’s needs), and practice-based coaching (teaching practices)</td>
<td>&quot;the use of thought provoking questions and having us realize things on our own”</td>
</tr>
<tr>
<td>interactions (language)</td>
<td>Teacher Interactions to Build Mathematical Thinking (from CM handout: Stop &amp; Look, Wait, Say what you see, Re-voice, Use descriptive language, Confirm/clarify children’s thinking, Comments/questions to invite/provoke thinking, See disagreements as learning opportunities, See mistakes as springboards for learning); teachers often describe as “language” includes teacher moves, teaching strategies</td>
<td>&quot;Help teachers identify the interactions they will use to scaffold the students' thinking around the Big Ideas (Use the Teacher Interaction sheet) &quot;</td>
</tr>
<tr>
<td>listen/ promote reflection</td>
<td>Regarding role of coach to help teachers reflect on their lessons, listen to teachers ideas and guiding them to decide how to apply new ideas themselves; Cognitive Coaching techniques</td>
<td>&quot;[Coach] asks questions that prompt teachers to think for themselves&quot;</td>
</tr>
<tr>
<td>logistics</td>
<td>Mention of materials, location, number of children, etc.</td>
<td>&quot;[IL] was able to hear what we needed from her in order to do the math games in the classroom. If we needed any supplies she was able to order them.&quot;</td>
</tr>
<tr>
<td>math content knowledge / instructional goal</td>
<td>References to mathematical &quot;big ideas&quot; or better understanding of math concepts (either teacher or child level):</td>
<td>&quot;I work with early childhood teachers to help them understand the big math concepts that children are creating and help&quot;</td>
</tr>
<tr>
<td>Topic</td>
<td>Description</td>
<td>Example</td>
</tr>
<tr>
<td>------------------------------</td>
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<td>--------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>&quot;mathematical goal&quot; &quot;big ideas&quot; &quot;clearly define instructional goal&quot;</td>
<td>Implement activities that will support that understanding in the classroom.</td>
<td>&quot;She showed my team and I how to help a child that was having trouble showing five using two hands. We learned how to put our fingers up to his fingers in order to help him show five using two hands. She showed us how to help them to move forward when playing great race game remember to say the number you get out loud...&quot;</td>
</tr>
<tr>
<td>modeling</td>
<td>Coach leads the lesson with children while the teacher watches (opposite of observing, co-teaching is in between observing and modeling) Originally conceived to refer to what happens IN the classroom, but also overlaps with role play during coaching meetings</td>
<td>&quot;I think it was our relationship over time that pushed teachers to try new things with math. For the most part, the more I got to know the teachers, the more they were willing to trust me and try new things...&quot;</td>
</tr>
<tr>
<td>monitor progress</td>
<td>Coach checks-in regarding teachers or center's goals from a previous session (following up on next steps)</td>
<td>&quot;to understand better were we where and where we want to take children further...&quot;</td>
</tr>
<tr>
<td>motivate / encourage</td>
<td>Coach motivates teacher. &quot;pushed teachers to try new things with math&quot; &quot;[teachers] put effort into it [the project]&quot; encourage, inspire, accountable</td>
<td>&quot;I think it was our relationship over time that pushed teachers to try new things with math. For the most part, the more I got to know the teachers, the more they were willing to trust me and try new things...&quot;</td>
</tr>
<tr>
<td>new ideas, insight</td>
<td>Coach offers an outside perspective</td>
<td>&quot;fresh pair of eyes&quot;, &quot;someone else's point of view&quot;</td>
</tr>
<tr>
<td>next steps / change / improve</td>
<td>Coach and teacher discuss what will happen after coach leaves: set goals, action plan &quot;do different&quot; &quot;generalize&quot;</td>
<td>&quot;During reflection, we talked about how the activity went and what we could do different.</td>
</tr>
<tr>
<td>observe</td>
<td>Coach passively observes the teacher's lesson with children without jumping in (opposite of modeling; co-teaching is in between observing and modeling)</td>
<td>&quot;When she observed me with the kids&quot; &quot;the coach saw me try the lesson&quot;</td>
</tr>
<tr>
<td>planning</td>
<td>Classroom teachers and their coach spend time together thinking through an activity before involving students in the classroom.</td>
<td>&quot;I was always asked how I would prepare for an activity. The coach would fine tune my words and introductions to an activity.&quot;</td>
</tr>
<tr>
<td>practice, pedagogy, instruction</td>
<td>Actions the teacher takes to facilitate student learning. Includes skills, instruction, pedagogy, teacher moves, &quot;interactions&quot;</td>
<td>&quot;I became more aware of utilizing math language to provoke children thinking in math.&quot;</td>
</tr>
<tr>
<td><strong>promote collaboration among coworkers</strong></td>
<td>Co-teachers are more intentional about planning together, sharing responsibilities during the lesson; assistant teachers take on larger role, feel included</td>
<td>&quot;flattened the hierarchy within each classroom team&quot; &quot;I felt that the coach helped me become more confident as a teacher 3, sometimes we feel that we don't make a difference but with this training I felt that we were all on the same page receiving the same training.&quot;</td>
</tr>
<tr>
<td><strong>&quot;real-time coaching&quot;</strong></td>
<td>Coach works alongside teacher during lesson. Coach may lead some parts or jump in to ask questions; co-teaching</td>
<td>&quot;you get one on one assists&quot;</td>
</tr>
<tr>
<td><strong>relationship building</strong></td>
<td>Coach builds a relationship with teacher: trust, &quot;really knew me&quot; &quot;got personal&quot;</td>
<td>&quot;Over time, they often shared personally with me and opened up about their teaching, students and sometimes, their personal lives too.&quot;</td>
</tr>
<tr>
<td><strong>role play / rehearse</strong></td>
<td>During coaching meeting (with no children present) coach and teacher(s) practice a lesson</td>
<td>&quot;I was able to choose [sic] the activities that I wanted to do with the children my coach was helpful and we would practice doing the activities on each other and say what we thought of what we had done&quot;</td>
</tr>
<tr>
<td><strong>use video</strong></td>
<td>Coach shows video clips to teachers (either of themselves or other teachers)</td>
<td>&quot;The benefit was she videotaped and we were able to see what we did&quot;</td>
</tr>
<tr>
<td>*<strong>full CM intervention</strong></td>
<td>When something is referenced that is about the Collaborative Math Intervention that is not specifically (or clearly) about coaching.</td>
<td>&quot;I tell people we have workshops that help teachers understand foundational math understandings we call big ideas. Then we go into sites and work with individuals, pairs or groups of teachers to plan, observe and debrief/reflect on the work.&quot;</td>
</tr>
<tr>
<td>*<strong>Learning Labs</strong></td>
<td>When something is referenced that is clearly and specifically related to Learning Labs and not other parts of the Collaborative Math intervention model</td>
<td>&quot;all teachers were given the same trainings&quot;</td>
</tr>
<tr>
<td>Code Title</td>
<td>Description</td>
<td>Example</td>
</tr>
<tr>
<td>------------------------------------</td>
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<td>-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>classroom practice</strong></td>
<td>Behavioral development, active, things teachers do and say with children, skills, teaching strategies, interactions, lessons, pedagogical choices</td>
<td>&quot;became more intentional in providing classroom experiences&quot;</td>
</tr>
<tr>
<td>• addressed a weak spot</td>
<td>Coach points out or teacher reflects on something that could be done differently</td>
<td>&quot;ideas on how to improve&quot;</td>
</tr>
<tr>
<td>• implemented new strategies</td>
<td>Coach encourages or teacher tries novel teaching approach; active and about actual action in practice (as opposed to &quot;knowledge of what to teach&quot;)</td>
<td>&quot;Remembering to ask questions after children give a reason for something...&quot;</td>
</tr>
<tr>
<td>• persisted in incorporation of new practices</td>
<td>Coach encourages or teacher tries new strategies; requires evidence of persistence, change over time, multiple iterations, not getting right the first time</td>
<td>&quot;most of the interactions they have been struggling with they are getting better at like say what you see&quot;</td>
</tr>
<tr>
<td><strong>dispositions</strong></td>
<td>Social/emotional development in relation to math: attitudes about the importance of math, beliefs that math is important, confidence about math teaching</td>
<td>At the beginning I felt a little apprehensive, mostly likely because math has always been an intimidating subject, but the coach made all of that disappear.</td>
</tr>
<tr>
<td>• attitudes</td>
<td>Teacher expresses attitude about mathematics; exciting, interesting. Relates to identity: &quot;not a math person&quot;</td>
<td>&quot;became more math hungry for the children&quot;</td>
</tr>
<tr>
<td>• beliefs</td>
<td>Teachers express belief that math is or is not important in early childhood classrooms (includes mention of incorporating more often or elsewhere in the curriculum as indirect reference to belief of importance)</td>
<td>&quot;We do a lot more daily math in the classroom&quot;</td>
</tr>
<tr>
<td>• confidence</td>
<td>Teacher mentions gain in or lack of confidence in math teaching; also includes &quot;comfort&quot; (confidence in own ability to do adult math coded under attitudes)</td>
<td>&quot;presented math confidently to our children&quot;</td>
</tr>
<tr>
<td>Category</td>
<td>Description</td>
<td>Example</td>
</tr>
<tr>
<td>------------------------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>disposition but no</td>
<td>Applied when there is a reference to a disposition but it is not clearly linked to math or coaching</td>
<td>&quot;she felt good about the activity&quot;</td>
</tr>
<tr>
<td>math or coaching</td>
<td></td>
<td></td>
</tr>
<tr>
<td>negative disposition</td>
<td>Coaching is hypothesized to positively impact dispositions; this code is used for negative attitudes, beliefs, and confidence</td>
<td>&quot;I talked to other teachers and they felt overwhelmed at times and disrupted by their coaches&quot;</td>
</tr>
<tr>
<td><strong>Knowledge</strong></td>
<td>Cognitive development, passive, math content, big ideas, developmental, learning trajectories; PCK - what teachers need to know about math to be effective with young children</td>
<td>&quot;the coach always bring the discussion back to the Big Ideas&quot;</td>
</tr>
<tr>
<td>how to teach it</td>
<td>Knowledge of instructional methods</td>
<td>&quot;different ways it can be implemented&quot;</td>
</tr>
<tr>
<td>better lesson planning</td>
<td>Planning for how to teach children has been enhanced or improved as a product of coaching. (code under knowledge when about knowing how to do it versus actually doing it which goes under practice)</td>
<td>&quot;My planning was always good but seen how children would do the activities and get feedback from my coach was even better.&quot;</td>
</tr>
<tr>
<td>what to teach</td>
<td>Content knowledge for teaching</td>
<td>&quot;purpose of the activity&quot;</td>
</tr>
<tr>
<td>who is taught</td>
<td>Knowledge of child developmental levels, assessments of individual children's abilities or interests</td>
<td>&quot;too advanced for the children&quot;</td>
</tr>
<tr>
<td><strong>Collaboration</strong></td>
<td>Increased collaboration within (Assistant Teachers) and across classrooms is mentioned as an outcome of coaching.</td>
<td>&quot;insure that both teachers have an equal voice in planning and reflecting&quot;</td>
</tr>
<tr>
<td>Full CM Model</td>
<td>When something is referenced that is about the CM model that is not specifically (or clearly) about coaching.</td>
<td>&quot;Ask for feedback about the math learning they got a the PD lab&quot;</td>
</tr>
<tr>
<td>Learning Labs</td>
<td>When something is referenced that is clearly and specifically related to Learning Labs and not other parts of the PD model</td>
<td>&quot;the labs are too long. I got very sleepy toward the ends of them&quot;</td>
</tr>
<tr>
<td>Code Title</td>
<td>Description</td>
<td>Example</td>
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<tr>
<td>accountability (coach holding teachers accountable)</td>
<td>The presence of the coach visiting the classroom creates a type of pressure that supports teachers following through with plans and goals.</td>
<td>&quot;We gained accountability because we knew we were going to be observed so we really had to do the work and get the different activities going in our classroom.&quot;</td>
</tr>
<tr>
<td>apprehension/math anxiety</td>
<td>When a teacher holds back in some way from the learning process because they are anxious about math, apprehensive about learning new techniques, etc.</td>
<td>&quot;It was difficult at first because I had to become open about learning new ways to teach my students math.&quot;</td>
</tr>
<tr>
<td>clear goals/outcomes</td>
<td>Coaching helps define outcomes &quot;same final idea of what we wanted to achieve&quot;; staff is &quot;on the same page&quot;</td>
<td>&quot;It was very beneficial because we would all be on board and have the same final idea of what we wanted to achieve.&quot;</td>
</tr>
<tr>
<td>coach on site</td>
<td>Coaches are there in person, can watch teachers teach, and answer questions as they come up; aka &quot;live-coaching&quot;, &quot;real-time&quot; coaching</td>
<td>&quot;but many benefits when the coach sat in the sessions. the coach offered ideas of how to improve the activity by modeling the suggestion and participating as needed .&quot;</td>
</tr>
<tr>
<td>coaching model flexibility</td>
<td>There is flexibility in how coaches can support teachers while still having fidelity to the model. Flexibility helps coaches be able to individualize how they are interacting and supporting teachers</td>
<td>&quot;Teachers can have very different levels of understanding of the big ideas, different levels of reflective thinking, different expectations of the coach...&quot;</td>
</tr>
<tr>
<td>communication with coach</td>
<td>Teachers were able to ask the coaches questions when needed without having to wait until a physical in person meeting</td>
<td>&quot;she went that extra mile answering questions through emails and phone calls until we knew that it was coming altogether&quot;</td>
</tr>
<tr>
<td>coverage / teacher physical absence</td>
<td>Coverage refers to finding another adult to supervise children so a teacher can participate in intervention inputs. Coverage issues could impact being able to go to Learning Lab, finding time for meetings, or having to adjust the quantity of time with a coach.</td>
<td>&quot;It would have probably made it easier to ensure we had coverage to make the meetings and support to implement ideas. This generally did not occur with us.&quot;</td>
</tr>
<tr>
<td>Engagement/Teacher Mental Absence</td>
<td>Teachers have many job responsibilities beyond the intervention, as well as personal issues that can affect their ability to fully participate. Includes mental absence such as reference to teachers feeling or appearing distracted, tired, overwhelmed but does not include physical absence such as being unable to attend a meeting (see coverage).</td>
<td>&quot;the third member in my classroom was very lost during our instruction and would sometimes veer off our instructional goal and confuse the children&quot;</td>
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<tr>
<td>Group Coaching = Teamwork / Collaboration</td>
<td>The group coaching model encouraged collaboration among co-teachers and across classrooms</td>
<td>It was beneficial for teachers to be coached as a group to have a common conversation around one idea/one lesson in order to build a common understanding and common goals and then reflect on those together</td>
</tr>
<tr>
<td>Inclusion of All Teachers</td>
<td>Including all of the teachers in the classroom--ie, assistant teachers -- facilitates collaboration and sharing the workload more evenly. It also may facilitate lifting up teacher assistants to have more confidence in their job/identity</td>
<td>&quot;the teachers all work well together. [IL] needs to insure that both teachers have an equal voice in planning and reflecting&quot;</td>
</tr>
<tr>
<td>Lack of Materials</td>
<td>Teachers did not have the resources to have/create the same activities as presented in the Labs.</td>
<td>&quot;limitations of not having similar materials as the ones in the lab.&quot;</td>
</tr>
<tr>
<td>Learning Speed</td>
<td>How quickly teachers are able to pick up/learn the math concepts and turn it around into classroom practice</td>
<td>&quot;some teachers may need to walk through a lesson to think about what they would say/do step-by-step whereas others may feel more comfortable with a general outline of the lesson.&quot;</td>
</tr>
<tr>
<td>Meetings (Schedule, Space, Duration)</td>
<td>Challenge of finding a time or place for group coaching meetings when full team can meet together. This is linked to coverage. Barrier when it doesn't go well, facilitative when it does</td>
<td>&quot;More communication to the teachers about when planning, observations, and reflections will be.&quot;</td>
</tr>
<tr>
<td>Relationship between Teacher and Coach</td>
<td>Comment or descriptor characterizing the relationship between coach and teacher; can be negative or positive</td>
<td>&quot;I felt as though she wasn't willing to get to know our classroom, our students, our teaching practices and philosophy, which made the coaching that much more difficult.&quot;</td>
</tr>
</tbody>
</table>
| opportunities to practice | Continued opportunities for teachers to practice increases their feelings of competence and mastery | "Having the teams practice the activity.... [IL] sees the value in having them walk through the activity -- both for anticipating student responses as well as practicing what they are going to say..."

| order of concepts (math content) | Referencing the order of what was taught first (or beginning), last (or at the end), or how concepts taught led into other concepts. Could be facilitative or inhibitory | "It seems as if the information given to us at the end was more clear than the information at the beginning."

| "outsider" point of view | A unique benefit of the coach being an outsider to the classroom teachers is they have a perspective that those on the inside may not be able to see | "...to have more than one person see how we implement math and to provide us with different techniques."

| performance anxiety (in front of group/in front of coach)/feeling judged | Group coaching model may be inhibitory for people that feel anxious about performing in front of a group, their co-teachers, or the coach. | "nervous and feeling like you are being evaluated"

| "putting on a show" | Teachers only make the changes when the coach is there--this is a barrier to sustainable change | "some teacher just do for showing off, and seeing they do not implement anything during the rest of the week. Only when the coach was here, and bother me that seeing they are good teachers and don’t bring those skills in a regular day."

| pre-existing burnout | This burnout could be from having a challenging classroom of children, having many other responsibilities, etc.--the CM model is not the cause of burnout, but the burnout influences the teacher's mental or physical availability to learn, change, etc. Related to engagement. | "Those meetings often came right off a heavy transition with the children..."

| presence of Instructional Leader (IL) | Feel supported by presence of IL or presence of IL stifled teachers from speaking freely. IL’s leadership style could also be facilitative or inhibitory | "he benefits of my instructional leader sitting in on a coaching session was beneficial if i missed some important information or did not understand something that the coach was telling me"
<table>
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<tr>
<th>time/ dosage</th>
<th>References to the quantity of time Coach spends with teachers-- includes requests for more; having time to do things/ the amount of time it takes to do something; feeling rushed</th>
<th>&quot;Coaches came once after each lab. I found the sessions very helpful and would love to be coached more than once following each session.&quot;</th>
</tr>
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<tbody>
<tr>
<td>user friendly ideas (games/activities)</td>
<td>Providing teachers with ideas, such as the games, that are easy to implement and try out facilitated the teachers being willing to, and successful at, attempting.</td>
<td>&quot;the activities, games and dot cards, were simple to initiate and weave into their daily routines.&quot;</td>
</tr>
<tr>
<td>Full CM Intervention</td>
<td>When something is referenced that is about the Collaborative Math intervention that is not specifically (or clearly) about coaching.</td>
<td>&quot;we know more math activities to do with children&quot;</td>
</tr>
<tr>
<td>Learning Labs</td>
<td>When something is referenced that is clearly and specifically related to Learning Labs and not other parts of the Collaborative Math intervention</td>
<td>&quot;To review each activity before diving into the next one during the Learning Labs.&quot;</td>
</tr>
</tbody>
</table>
Sets

- Attributes can be used to sort collections into sets.
- The same collection can be sorted in different ways.
- Sets can be compared and ordered.

Number Sense

- Numbers are used many ways, some more mathematical than others.
- Quantity is an attribute of a set of objects and we use numbers to name specific quantities.
- The quantity of a small collection can be intuitively perceived without counting.

Counting

- Counting can be used to find out “how many” in a collection.
- Counting has rules that apply to any collection.

Number Operations

- Sets can be changed by adding items (joining) or by taking some away (separating).
- Sets can be compared using the attribute of numerosity & ordered by more than, less than and equal to.
- A quantity (whole) can be decomposed into equal or unequal parts; the parts can be composed to form the whole.

Pattern

- Patterns are sequences (repeating or growing) governed by a rule; they exist both in the world and in mathematics.
- Identifying the rule of a pattern brings predictability and allows us to make generalizations.
- The same pattern can be found in many different forms.
Measurement

- All measurement involves a “fair” comparison.
- Many different attributes can be measured, even when measuring a single object.
- Quantifying a measurement helps us describe and compare more precisely.

Data Analysis

- The purpose of collecting data is to answer questions when the answers are not immediately obvious.
- Data must be represented in order to be interpreted, and how data are gathered and organized depends on the question.
- It is useful to compare parts of the data & to draw conclusions about the data as a whole.

Spatial Relationships

- Relationships between objects and places can be described with mathematical precision.
- Our own experiences of space and two-dimensional representations of space reflect a specific point of view.
- Spatial relationships can be visualized & manipulated mentally.

Shape

- Shapes can be defined and classified by their attributes
- The flat faces of solid (three-dimensional) shapes are two-dimensional shapes.
- Shapes can be combined and separated (composed and decomposed) to make new shapes
APPENDIX P

TEACHER INTERACTIONS FOR MATHEMATICAL THINKING
- **Stop & Look**
- **Wait**
- **Say what you see**
- **Re-voice**

- **Use descriptive language**
- **Check with the children**
- **Comments/questions to invite/provoke thinking**
- **See disagreements as learning opportunities**
- **See mistakes as springboards for learning**

<table>
<thead>
<tr>
<th>Teacher Interaction</th>
<th>Reasoning Behind Interaction</th>
<th>Example</th>
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<tbody>
<tr>
<td><strong>Stop &amp; Look</strong></td>
<td>Through observation, forming a hypothesis or generating theories based on student behavior. Thinking about what I will say to the child based on what I have observed them doing.</td>
<td>I am watching Carmen putting objects into two piles. One pile has an assortment of bottle caps and jungle animals and the other pile has plastic fruit and lego pieces. I wonder why she has put the objects in those groups and I begin to look for ways that the members of the groups are the same and how the two groups are different. Teacher is fully present, without using words or actions</td>
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<tr>
<td><strong>Wait</strong> (at least 2 sec) before responding</td>
<td>Allow child the time to react or respond to a teacher prompt.</td>
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<tr>
<td><strong>Say what you see</strong></td>
<td>Based on careful observation and hypothesis, use precise language to describe what you see, then check for confirmation. Provide labels to actions or structures that are mathematical. Children are engaged in mathematical behaviors many times during the day; language gives the opportunity to replicate what was done and to talk about it with others. Language gives you the materials to critique the reasoning of others.</td>
<td>“I notice that you have put several brown jungle animals in a group with dark brown bottle caps. I also notice that the legos and the fruits are either red or yellow. I wonder why did you put those objects together.” “I heard you say …”</td>
</tr>
<tr>
<td><strong>Re-voice</strong></td>
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<tr>
<td><strong>Use descriptive language</strong></td>
<td>Provides precise language about attributes, including number, numerosity, and position. Surfaces relationships between objects. Increased precision vs. evaluative language</td>
<td>“I see that you are flipping the trapezoid the other way to see if it fits in the spot next to the hexagon.” “I see that you put the buttons that have only two holes in this pile and the ones that have more than two holes in another pile.”</td>
</tr>
<tr>
<td><strong>Check with the children</strong></td>
<td>Ask questions to confirm children’s thinking about the work they are engaged in.</td>
<td>I wonder if you were thinking about color when you made your groups or were you thinking about something else?”</td>
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<tr>
<td><strong>Make comments / ask questions to invite / provoke children’s thinking</strong></td>
<td>Promoting problem solving. Questions are used to pose problems and to get children to think deeper about the math.</td>
<td>“You said this green apple belongs in the group. How is that?” “Diana said the raisins belong with the bottle caps; what do you think?” “You used different shapes to make the top part of this pattern block puzzle but for the bottom part you always used the square and the triangle. Hmmm…. I wonder why that is”</td>
</tr>
<tr>
<td><strong>See disagreements as learning opportunities</strong></td>
<td>Looking for opportunities to critique the reasoning of others. It’s not about being right or wrong; it’s the conversation that results from engaging in thinking critically and explaining clearly. Put two things side by and you get different responses.</td>
<td>“I’m hearing two different things. How can this be? Can you explain your thinking?”</td>
</tr>
<tr>
<td><strong>See mistakes as a springboard for learning</strong> as opposed to an instance to immediately correct</td>
<td>Using children’s misconceptions or mistakes as a window into their current understanding. This gives teachers a clearer direction of how to intervene to best support the student.</td>
<td>The class has counted that there are 17 children present, having breakfast. The teacher asks the child how many milks do they need if everyone gets a carton of milk. The child says “4” and the teacher asks why. The child responds “because that’s enough”. The teacher gives him 4 milk cartons to give to the classmates and he sees and then says that there are not enough. The teacher asks him what should they do, and he says they need more. The teacher gives him a few cartons of milk at a time until he has given everyone a carton of milk. This interaction has given the teacher information about his developing understanding of cardinality, magnitude, and one-to-one correspondence.</td>
</tr>
</tbody>
</table>
REFERENCE LIST


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VITA

Prior to pursuing her Ph.D. at Loyola University/Erikson Institute, Dr. Lauren Solarski earned a M.S. in Elementary Education and Social Policy from Northwestern University, and a B.A. in English Literature from DePaul University. She began her career as a Kindergarten teacher in Chicago through AmeriCorps in 2008 and has experience as a certified teacher for children in grades PreK-2. In 2014, the National Science Foundation on behalf of the White House Office of Science and Technology Policy named Dr. Solarski an Illinois State Finalist for the Presidential Award for Excellence in Mathematics and Science Teaching.

Dr. Solarski was also awarded an Erikson Institute Doctoral Fellowship in 2014 and joined the Early Math Collaborative as a Research Assistant and Professional Development Facilitator. She later worked as a Math Coach collaborating with teachers and leaders in elementary schools and Head Start centers. Additionally, Dr. Solarski has taught adults as Part-Time Faculty in Child Development and Teacher Education for both graduate and community college programs.

Dr. Solarski has published in Young Children and she has presented at conferences for organizations including: National Association of Young Children, National Council of Teachers of Mathematics, National Head Start Association, and Illinois Education Research Council. She has been invited to speak by: University of Denver, Wisconsin Mathematics Council, Argonne National Laboratory, and Chicago Public Schools. She was also awarded “Best Qualitative Poster” at the 2018 Loyola Graduate School Interdisciplinary Research Symposium.
In 2017, Dr. Solarski co-founded the National Association for the Education of Young Children’s *Early Math Interest Forum* and continues advocating around issues of equity and access in her facilitator role. As an Erikson/Loyola Student, Dr. Solarski chaired the Doctoral Student Association from 2016 to 2018. She also served as the Education Coordinator for her neighborhood’s community organization from 2017 to 2020.