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Professional Learning Communities (PLCs) for Early Childhood Science Education

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PROFESSIONAL LEARNING COMMUNITIES (PLCs) FOR EARLY CHILDHOOD SCIENCE EDUCATION

by

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PROFESSIONAL LEARNING COMMUNITIES (PLCs) FOR

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This study explored the content, processes, and dynamics of Professional Learning Community (PLC) sessions. This study also investigated changes in preschool teachers' attitudes and beliefs toward science teaching after they participated in two different forms of PLCs including workshop and face-to-face PLC as well as workshop and online PLC. Multiple sources of data were collected for this study including participant artifacts and facilitator field notes during the PLC sessions.

The participants in this study were eight teachers from NAEYC-accredited child care centers serving 3- to 5-year-old children in an urban Midwest city. All teachers participated in a workshop entitled, "Ramps and Pathways." Following the workshop, the first group engaged in face-to-face PLC sessions and the other group engaged in online PLC sessions. Qualitative data were collected through audio recordings, online archives, and open-ended surveys. The teachers' dialogue during the face-to-face PLC sessions was audiotaped, transcribed, and analyzed for emerging themes. Online archives during the online PLC sessions were collected and analyzed for emerging themes. Four main themes and 13 subthemes emanated from the face-to-face sessions, and 3 main themes and 7 subthemes emanated from the online sessions. During the face-to-face sessions, the teachers worked collaboratively by sharing their practices, supporting each other, and planning a lesson together. They also engaged in inquiry and reflection about their science teaching and child learning in a positive climate. During the online sessions, the teachers shared their thoughts and documentation and revisited their

science teaching and child learning. Five themes and 15 subthemes emanated from the open-ended survey responses of face-to-face group teachers, and 3 themes and 7 subthemes emanated from the open-ended survey responses of online group teachers. Quantitative data collected in this study showed changes in teachers' attitudes and beliefs toward science teaching. Face-to-face group teachers' comfort with planning and doing different science activities increased significantly after the workshop and after the combination of workshop and face-to-face PLC.

This study contributes to the research about various forms of professional development and their process and outcome in early childhood science education and informs early childhood professional communities of creative ways to improve science teaching and learning.

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CHAPTER 1

INTRODUCTION

Early childhood science education is important for several reasons: it contributes to positive attitudes toward science, produces a better understanding of scientific concepts and scientific thinking later in life, and influences other domains of development. Additionally, young children have the ability to reason scientifically (Hong & Diamond, 2012), and so it is critical to support young children's natural curiosity and interests, scientific thinking, and other developmental domains with meaningful learning contexts (Eshach & Fried, 2005; French, 2004; Worth & Grollman, 2003).

Teachers' guidance and support are critical for children to have positive attitudes toward science, understand scientific concepts, and do science. Teachers can help children consistently practice the scientific problem-solving process, and in turn, advance their understanding of important science concepts. Also, teachers can provide children with meaningful science activities that feature interesting and connected materials. These experiences foster inquiring attitudes in children, which helps them come to appreciate the world and maintain their curiosity. Also, children gain a respect for evidence and learn a collaborative endeavor (Worth & Grollman, 2003). Teachers are key influences for children's science learning in that they create classroom environments, plan activities, and interact with children every day.

We know why early childhood science education is important (Eshach & Fried, 2005; French, 2004; Gelman, Brenneman, Macdonald, & Roman, 2009; Worth & Grollman, 2003). Little is known, however, about how we can support children's science learning effectively. We need more research regarding what works best and what matters in early childhood science education (Greenfield et al., 2009).

Early childhood teachers are encouraged to plan and provide high-quality science experiences in order to engage children in in-depth science explorations for an extended period of time. Early childhood teachers, however, reported discomfort with teaching science, limited content and pedagogical knowledge, and a lack of professional support (Greenfield et al., 2009; Kermani & Aldemir, 2015). Therefore, it is critical to provide teachers with professional development (PD) opportunities in early childhood science education that enable them to understand what to teach and how to teach it effectively and help them become confident and comfortable teaching science to young children. For PD to be successful, it should focus on the children's learning and on improving teachers' knowledge and skills. Such PD should also be sustainable and involve someone who can help facilitate and motivate the group, especially early on (Abell & Lee, 2008; Darling-Hammond & Richardson, 2009; Koba, Wojnowski, & Yager, 2013; Nelson, LeBard, & Waters, 2010).

One form of PD is the professional learning community (PLC). A PLC is a group of professionals who are involved in continuous learning and inquiry, which is accomplished by collaboratively and collectively reflecting on what they do to improve their teaching and, in turn, to support children's learning (Hord, 1997; Stoll, Bolam, McMahon, Wallace, & Thomas, 2006). PLCs, however, have many challenges. For example, they are affected by structural, relational, and external factors (Hord, 2009; Louis, Marks, & Kruse, 1996; Stoll et al., 2006). Online PLCs may resolve some of those challenges in that they enable teachers to participate in their PLC wherever they are located. In addition to this advantage, some teachers may feel more comfortable in sharing their ideas and practices in cyberspace than they would in face-to-face sessions.

Little empirical research exists about face-to-face and online PLCs and their operation, effectiveness, and challenges in early childhood science education. Furthermore, little is known about what works best, what matters, and what challenges exist in the various forms of PD (Buysse, Winton, & Rous, 2009; Greenfield et al., 2009; Sheridan, Edwards, Marvin, & Knoche, 2009). The current study is poised to answer some of those questions by focusing on PLCs.

Preschool teachers, in particular, may have more challenges in teaching science in that 1) they are expected to teach other content areas as well as science, 2) they possess limited science content and pedagogical knowledge, and 3) they lack professional and social support in teaching science. In the current study, main components of two different forms of early childhood PLCs (i.e., face-to-face and online) were investigated. In addition, this study aimed to examine the processes and dynamics of PLCs to better understand their components that may make a difference in early childhood teachers' attitudes and beliefs about teaching young children science. Before PLCs, teachers participated in a specialized training (i.e., workshop) so they were able to use the content of the specialized training as a context of PLCs.

This study will contribute to the research about the various forms of PD and their effectiveness in early childhood science education using quantitative and qualitative data. Specifically, this study will be meaningful in that it includes in-depth analyses of the face-to-face and online PLC sessions. This research will inform early childhood professional communities of creative and collaborative ways to improve science teaching and learning in early childhood settings.

CHAPTER 2

LITERATURE REVIEW

Early Childhood Science Education

Why Science in Early Childhood Education?

Children have a natural tendency to explore the world, and early exposure to science activities with rich verbal and nonverbal sharing of information leads to better understanding of the scientific concepts and processes later (Eshach & Fried, 2005; Patrick & Mantzicopoulos, 2015; Worth & Grollman, 2003). Science education with direct experience with materials, events, and ideas can fulfill and extend children's natural curiosity and appreciation for nature in that it helps children's positive attitude towards science and better understanding of science concepts and process later. Furthermore, children can reason scientifically, and science is an effective means for developing children's scientific thinking and inquiry (Eshach & Fried, 2005; French, 2004; Worth & Grollman, 2003). When educators provide meaningful learning environments and nourish children's curiosity and interests with support and guidance, children can have more opportunities to fully develop scientific concepts and scientific process skills.

In addition, science education is important in that it supports many domains of development (e.g., social, cognitive, emotional, and language development) (Gelman et al., 2009; Holt, 1977; Worth & Grollman, 2003). Science activities involving counting, measuring, and comparing promote children's mathematical skills. Recording observations and sharing and discussing ideas in science activities enhance children's language and literacy skills. Through science education, children learn new words and explain the scientific process using multiple formats of representation. Comparing and contrasting in science education encourage children's reasoning skills. In addition, cooperating and sharing during science education facilitate children's social and emotional skills.

However, early childhood science education is an underexplored domain. There is little empirical research regarding effective science teaching practices (Greenfield et al., 2009). In addition, science learning activities, materials and area in preschool are less popular among teachers and tend not to be used by teachers and children meaningfully. According to interviews with preschool teachers, many of them reported discomfort with their knowledge of science and difficulties in finding time to do science activities (Greenfield et al., 2009). This means that children are losing an opportunity to benefit from science learning environments (Nayfeld, Brenneman, & Gelman, 2011). Therefore, early childhood educators are in great need for effective professional development opportunities around science teaching and learning.

Early Childhood Professional Development

What Is Professional Development?

Professional development (PD) is defined as a variety of learning, training, development opportunities, and experiences that improve the effectiveness of teaching with various support (Buysse et al., 2009; Cunningham, Etter, Platas, Wheeler, & Campbell, 2015; Hong, Torquati, & Molfese, 2013). Goals for PD in early childhood education are to improve teachers' knowledge, skills, dispositions, and practices and promote a culture for ongoing professional growth (Sheridan et al., 2009).

Successful early childhood PD is ongoing and intentional; highlights specific skills and goals rather than general ones; encourages teachers to set their own goals and engage in self-reflection throughout the process after research-based practices are recommended to them; provides teachers with instructional resources such as activity guides, summaries of key principles, and lists of further reading; provides opportunities for application and practice of newly acquired knowledge and skills; encompasses a sequence of active learning experiences that build on each other; and promotes building a professional learning community in which teachers use each other as learning resources and collaborate toward a shared goal (Cunningham et al., 2015; Fukkink & Lont, 2007; Vescio, Ross, & Adams, 2008).

Forms and Processes in Early Childhood Professional Development and Their Challenges

Early childhood PD can take various forms, such as specialized training, coaching, consultation, and professional learning communities (Sheridan et al., 2009). *Specialized training* includes workshops, conferences, presentation, lectures, and discussions. This form tends to provide generalized information and knowledge to groups with limited follow-up support and feedback. *Coaching* is used to reinforce skill development and application using observations, demonstrations, guided practice, self-reflection, feedback, and evaluation. A coach is a third party who usually works one-on-one with coachees. The coach's role is helping individuals increase their effectiveness and reflect on their thinking and behavior (Schwarz, 2002). *Consultation* includes helping consultees' concerns through systematic problem solving, social influence, and professional support. A consultant is a third-party expert who has expertise in a particular area. The consultant's role is helping a client make informed decisions in a certain situation (Schwarz, 2002). *Professional learning communities* include ongoing PD groups of individuals and a complex set of social relationships. In professional learning communities, teachers themselves are the experts learning from one another as they share their children's work and lesson plans (Sheridan et al., 2009).

Coaching, consultation, and professional learning communities are considered as collaborative PD forms in early childhood education, in that these forms support collaboration and change (Buysse et al., 2009). Although individualized PD forms such as coaching, mentoring, and consultation with ongoing support and feedback were found to be effective in early childhood PD in many studies (Downer, Kraft-Sayre, & Pianta, 2009; Koh & Neuman, 2009; Podhajski & Nathan, 2005; Powell & Diamond, 2013), it tends to be labor intensive and costly, in that a coach, mentor, or consultant has to travel to meet with teachers and support them individually. In addition, coaching and consultation tend to be short term and in small scale. On the other hand, professional learning communities are ongoing and support sustained changes for teachers by encouraging them to share their knowledge, skills, and practices and work together as a team (Hong et al., 2013; Sheridan et al., 2009; Wesley & Buysse, 2006). Recently, the Internet was used to provide online communities to support teachers' professional learning, and this method has been successful in improving teaching quality (Lock, 2006; Pianta, Mashburn, Downer, Hamre, & Justice, 2008).

The process of PD is not linear but dynamic (Sheridan et al., 2009) and can explain how or why changes and growth happen and how teachers transfer knowledge to practice during PD experiences. Initially, PD was considered as an outside-in process, in which changes and improvements come from the outside (e.g., lectures, readings, demonstrations, coaches, consultants, etc.). More recently, however, PD has been considered as an inside-out process, in which changes and growth come from the inside (e.g., individuals) with ongoing study of best practices, reflection, and collaboration with other teachers. Therefore, in order to fully understand what is related to changes in practice, we need to examine the process and form and their interactions as well as other influencing factors (Hong et al., 2013; Sheridan et al., 2009; Wesley & Buysse, 2006).

Among different forms of PD, specialized training (i.e., workshops) has been most frequently used (Snell, Forston, Stanton-Chapman, & Walker, 2013). However, a workshop has limitations in that it tends to be a one-time event—not transformative, not sustainable—and leaves teachers isolated following the workshop (Cunningham et al., 2015; Downer et al., 2009; Lonigan, Farver, Phillips, & Clancy-Menchetti, 2011).

There is a growing body of research supporting sustainable effects of professional learning communities (PLCs) or collegial study groups in PD (Wesley & Buysse, 2006). Cunningham et al. (2015) investigated the effects of preschool teacher study groups. The goal of this study was to promote teachers to work collaboratively toward deepening content knowledge and integrating research-based practices into teaching. A small group of teachers in this study met twice a month for two hours in a designated room with a knowledgeable facilitator, and 11 to 15 sessions were conducted. Each session in this study followed a four-step process: (1) review, (2) content presentation, (3) practice, and (4) preparation. During the first step, *review*, teachers discussed their assignments and reflected on what worked and what didn't and the challenges faced in implementing new activities and strategies in their classrooms. They also read a two-page research-based article as an introduction to new concepts. During the second step, *content presentation*, the facilitator gave an interactive and informative presentation (25-45 minutes), with slides that included guiding questions at the beginning. The slides were designed to help teachers build knowledge. Followed by the presentation, the facilitator modeled activities using best practices. The third step, *practice*, was designed for teachers. Teachers had an opportunity to practice the skills, strategies, and activities that they learned in pairs or small groups. Teachers received feedback from partners. Teachers shared their experiences with the whole group and then developed a specific plan to implement the new activities, strategies, and skills with children in their classrooms. This opportunity enabled teachers to integrate new knowledge into their own practices. During the last step, *preparation*, the facilitator reviewed the session, discussed new assignments, and previewed the next session. There were significant changes in teachers' content and pedagogical knowledge and children's gains after the use of this relationship-based PD, specifically the teacher study group. PLCs seem promising for sustainable effects on teacher practices. However, PLCs have challenges because teachers reported that they have limited time and energy and limited financial support (Taylor, Dunster, & Pollard, 1999), which may make it hard for teachers to participate in PLCs. More research is necessary to investigate sustainable effects of PLCs and the mechanisms for sustainable individual and group changes (Sheridan et al., 2009).

In sum, there are various forms of early childhood PD. However, little is known about how different forms and how different combinations of forms affect changes in teachers' practices and children's learning (Buysse et al., 2009; Sheridan et al., 2009). In addition, much less is known about various factors that facilitate or impede individual or group changes. More research is needed about the process of PD in regards to how teacher's acceptance to change, supportive relationships among teachers, or personal theories of change affect their changes and growth as an early childhood professional (Sheridan et al., 2009).

Early Childhood Professional Development in Science Education

The NSTA recommended that teachers need professional development (PD) experiences that engage them in learning science principles in an interactive, hands-on approach, enabling them to teach about science principles appropriately and knowledgeably; that are ongoing and science specific; that help them understand how children learn science practices; that inform them about a wide range of strategies for teaching science effectively; and that include the use of mentors to provide ongoing support for educators for the application of new learning (NSTA, 2014). For science PD to be successful, it should focus on children's learning, improve teachers' knowledge and skills, be sustainable, and include someone who can help facilitate and motivate the group, especially at the beginning phase of it (Abell & Lee, 2008; Darling-Hammond & Richardson, 2009; Koba et al., 2013).

PD in science education is required to emphasize both content and pedagogical knowledge. Content knowledge refers to the foundational knowledge teachers are expected to have in a specific domain, such as physical science, life science, earth science, the nature of science, technology, etc. Pedagogical knowledge means an understanding of how to teach science, how to implement inquiry activities, and how children learn science. Teachers need both content and pedagogical knowledge to facilitate children's science learning process more effectively (Cunningham et al., 2015; Kanter & Konstantopoulos, 2010). Similarly, effective and long-lasting science PD programs include epistemic, procedural, and social components (Hong et al., 2013; Samarapungavan, Mantzicopoulos, Patrick, & French, 2009). In order to enhance children's science learning, teachers need support in what to teach (i.e., content support), how to teach it effectively (i.e., pedagogy support), and how to work with others and share their practices effectively (i.e., social support). There is a significant need for research that identifies effective science PD components (e.g., content knowledge, pedagogical knowledge, and social support) in changing early childhood teachers' science practices that will eventually affect children's learning.

Professional Learning Community

What Is a Professional Learning Community?

A professional learning community (PLC) is defined as groups of people who share and integrate their practice in a learning-oriented, inquiry-based, collaborative, inclusive, reflective, ongoing, and improving way (Hord, 1997; Stoll et al., 2006). In this sense, PLCs emphasize notions such as collegiality, inquiry, reflection, and self-evaluation.

In the field of early childhood education and intervention, community of practice is a more commonly used term instead of professional learning community, although the two share the same goals. Communities of practice are defined as groups of teachers who have a common professional interest and share their knowledge and practices (Helm, 2007; Wenger, 1998; Wenger, McDermott, & Snyder, 2002).

PLCs can be explored using Vygotsky's sociocultural theory (Vygotsky, 1978). Teachers share their experiences and understandings with other teachers in PLCs, and this socially mediated learning process may facilitate individual teachers' changes and development. In Vygotsky's perspective, teachers in PLCs internalize socially and externally acquired knowledge and skills and change their teaching practices at the individual level. Teachers' social interactions and reflection are promoted by socially accepted expectations and shared practices in PLCs. Therefore, socially created settings such as PLCs can improve teacher learning.

How Does a Professional Learning Community Work?

Teachers participating in PLCs work collaboratively to improve child learning by engaging in continuous collective learning (i.e., a continuous cycle of reflection and action) of their own. PLCs are characterized by a focus on learning, collaboration among professionals, shared leadership, and using reliable and research-based resources and results to guide growth and improvement (Mundry & Stiles, 2009). In this sense, PLCs can erase isolation, sustain commitment, and increase collective learning, collaboration, and accountability among peers.

Through PLCs, teachers can have reflective dialogues and conversations about classroom issues or problems, examine their practices, observe and analyze each other's practices, and plan and develop curriculum jointly. In addition, PLCs enable teachers to build collective knowledge and participate in cooperative learning as well as to build the sense of interdependence and community. Teachers build and develop PLCs by focusing on evidence (e.g., a child's work), analyzing and reflecting on the evidence, and changing their teaching practices collectively and collaboratively (Stoll et al., 2006).

PLCs are not merely a new way for teachers to work together on their tasks, but rather a structure for continuous learning and application of knowledge (Mundry & Stiles, 2009). PLCs are the inquiry groups that provide consistent and sustained support through collaboration, enable teachers to embed the practices in their own classroom settings, and aim at improving children's learning. In PLCs, everyone is a learner and creates a learning culture.

Research about Professional Learning Community

Empirical studies showed positive effects of PLCs on both teachers and children (Guo, Kaderavek, Piasta, Justice, & McGinty, 2011; Vescio et al., 2008). After participating in PLCs, teachers gained motivation, self-confidence, and leadership skills as well as increasing knowledge on science. In addition, children performed better on the scientific knowledge and skills' assessment and were engaged more frequently in hands-on science activities (Weiser, 2012). In particular, collegiality and collaboration seemed to be the key components for success. High levels of preschool teachers' collegiality and collaboration were positively related to teachers' attitude toward teaching and job satisfaction and gains in children's language and literacy skills (Guo et al., 2011; McGinty, Justice, & Rimm-Kaufman, 2008).

Similarly, after participating in PLCs, elementary school teachers reported that they felt less isolated, more satisfied, and more committed to goals, and that they had a shared and collective responsibility for children's learning and development. In addition, teachers tended to have new knowledge and beliefs about teaching and children's learning by being well informed, professionally renewed, and motivated to inspire children and make significant and lasting changes and adaptations to teaching. Furthermore, children whose teachers participated in PLCs learned science better (Hord, 1997).

In sum, PLCs have been shown to be effective for teachers at the elementary school level. Therefore, it is reasonable to hypothesize that PLCs may change preschool teachers' attitudes toward teaching young children science concepts and practices as well.

Professional Learning Communities in Early Childhood Education—Benefits and Challenges

Early childhood education settings are organizations with interrelated values and decision-making processes. The climate of an early childhood setting tends to support a sense of shared purpose and collegiality among teachers (Ackerman, 2008), which may make it easier to implement PLCs. In addition, in most typical early childhood classrooms, there are at least two teachers (e.g., two lead teachers or one lead and one assistant teacher). In considering the collaborative nature of PLCs, it is fairly reasonable to assume that early childhood teachers know how to build collaborative relationships and share ideas with one another.

However, early childhood teachers may encounter challenges in working with PLCs. In general, PLCs are influenced by a number of factors: (1) structural factors (e.g., size, forms of organization, time, space, etc.); (2) human and social resources (e.g., an individual's openness to change, group dynamics, relationships among participants, supportive leadership, feedback on instruction, etc.); and (3) external factors (e.g., partnerships, networks, etc.) (Hord, 2009; Louis et al., 1996; Stoll et al., 2006).

Early Childhood teachers tend to have limited energy and time as well as limited financial support (Taylor et al., 1999). This lack of structural resources makes them harder to commit to PLCs. In addition, individual teacher characteristics and group dynamics can influence the effectiveness of PLCs.

Online PLCs may resolve some challenges in that they enable teachers to participate in their communities wherever they are located. In addition, some teachers may feel more comfortable sharing their ideas and practices in cyberspace than doing so in face-to-face sessions.

Online Professional Learning Communities

New technologies can increase collegiality and collaboration among participants in PLCs. Communication technologies and innovative cyber tools enable educators to have online PLCs at a distance, and online PLCs are growing continuously in online platforms (Fulton & Britton, 2011; Mundry & Stiles, 2009; Palloff & Pratt, 1999). However, technology by itself does not create and develop online PLCs. Facilitators who guide participants are necessary (Fulton & Britton, 2011), and they play diverse roles in online PLCs. A facilitator is a neutral third party who is acceptable to all participants of the group and who has no decision-making authority. The facilitator's role is helping a group improve its effectiveness by intervening in group structure and process. Facilitators in online PLCs support teachers' growth by providing collaborative tasks, facilitating active discussion, and promoting critical thinking and research skills (Palloff & Pratt, 1999).

Facilitators in online PLCs have four roles: 1) *pedagogical role*, 2) *social role*, 3) *managerial role*, and 4) *technical role*. The pedagogical role includes actions such as probing, asking questions, providing feedback and instruction, simulating the discussion, synthesizing participants' comments, and referring to experts or outside resources in the field. The social role includes affective support, interpersonal communication, keeping the communication flowing, and setting a positive tone. The managerial role includes actions such as designing, coordinating, and overseeing. The technical role includes actions such as helping and guiding in terms of technology use (Maor, 2003).

Empirical research about online PD for K-12 teachers found that it improved teachers' understandings, knowledge, and implementation of instructional practices. Using online modules, teachers conducted an instructional strategy in their classrooms, reflected their implementation using children's work, revised their implementation, and discussed what worked, what they learned, and what children learned. Teachers reported positively about its efficacy, maximum flexibility (e.g., information available at any time through online), and individual and immediate support provided by the online PD (Little & King, 2007).

Videoconferencing, cyber mentoring, and discussion forums can be used for collaborative distance learning. These tools are used for teachers at distant sites to share, discuss, and analyze their practice. These tools enable teachers to see and hear one another from remote sites and promote sustainable learning and collaboration among participants (Johnson, Maring, Doty, & Fickle, 2006; Lowes, Lin, & Wang, 2007; Pringle, Klosterman, Milton-Brkich, & Hayes, 2010).

CHAPTER 3

METHODOLOGY

Current Study

Specialized training and social support are important components of early childhood teachers' professional development (PD). Early childhood PD literature recognizes the importance of sustainable Professional Learning Communities (PLCs) in developing high-quality early childhood teachers, especially in the areas about which teachers do not feel efficacious; however, more empirical research is needed to answer foundational questions to explore PLCs' operation, effectiveness, and challenges in early science childhood education (Greenfield et al., 2009). The current study aimed to investigate the content, processes, and dynamics of PLC sessions; and also examined changes in preschool teachers' attitudes and beliefs toward science teaching after they participated in two different forms of PLCs: 1) specialized training (workshop) + face-to-face PLCs and 2) specialized training (workshop) + online PLCs. This study contributes to the research about various forms of PD and their process and outcome in early childhood science education and informs early childhood professional communities of creative ways to improve science teaching and learning in early childhood settings.

Research Questions

1. What are emerging themes of teachers' conversations and interactions during the face-to-face PLC sessions? How are they similar to and different from those from online PLC sessions?

2. What are emerging themes of teachers' postings and interactions during the online PLC sessions? How are they similar to and different from those from face-to-face PLC sessions?
3. Do preschool teachers' attitudes and beliefs toward science teaching change after they participate in a specialized training and face-to-face PLCs?
4. Do preschool teachers' attitudes and beliefs toward science teaching change after they participate in a specialized training and online PLCs?
5. What are teachers' perceptions of face-to-face PLCs?
6. What are teachers' perceptions of online PLCs?

Method

Study Design

This study used an in-depth case study design to examine the complexities of a system (Clark & Creswell, 2014). This study design enabled in-depth explorations and provided rich information to better understand the content, processes, and dynamics of PLCs and teachers' PLC experiences. A thematic approach was used to explore and describe emerging themes during the PLC sessions (Clark & Creswell, 2014). During the PLC sessions, the teachers were guided to share their knowledge and practices and work collaboratively and collectively to improve their teaching practices through continuous discussion and learning.

Procedure

Recruitment. Figure 3.1 shows all the processes of data collection in sequence. Fourteen NAEYC-accredited child care centers (i.e., 14 of 99) were selected from a 2015 listing of all licensed child care centers in Lincoln. A homogeneous group (i.e., teachers from NAEYC-accredited centers) was selected to minimize the effect of diversity in characteristics of participants. A letter of invitation was sent to the director of each center, and the director was asked to distribute the invitation letter and a copy of study flyer to their preschool teachers. The invitation letter included a survey link with questions about their demographic information (see Appendix A) and attitudes and beliefs toward science teaching (Maier, Greenfield, & Bulotsky-Shearer, 2013) (see Appendix B). Preschool teachers who agreed to participate in this research completed the survey online through Qualtrics. A consent form was included with the survey link, and completing the survey implied that they consented to participate.

Eight teachers serving 3- to 5-year-old children agreed to participate in this study. Teachers by center were randomly assigned to either a face-to-face PLC (4 teachers from 2 centers) or an online PLC group (4 teachers from 3 centers) in order to minimize the contamination and logistics-related issues. The centers were randomized to condition and then the teachers who were part of a center were subsequently assigned to the same condition.

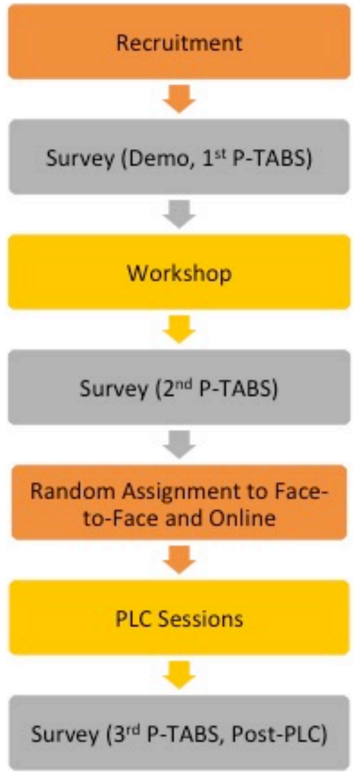


Figure 3.1. Processes of Data Collection

Survey. Four surveys were used in this study: 1) Teacher Demographic Survey (see Appendix A); 2) The Preschool Teachers' Attitudes and Behaviors towards Science (P-TABS) (Maier et al., 2013) (see Appendix B); 3) Online PLC Participating Teacher Survey (see Appendix C); and 4) Post-PLC Teacher Survey (see Appendix D). Teachers completed the P-TABS survey three times (i.e., before the workshop, after the workshop, and after the PLC sessions). Specifically, before attending the workshop, both groups of teachers (i.e., face-to-face and online) completed the Teacher Demographic Survey and the first round P-TABS survey. After attending the workshop and before participating in the PLC sessions, both groups of teachers completed the second round P-TABS survey. During the PLC sessions, online PLC group teachers completed a short online survey about their online contexts (e.g., how long they stayed logged into the session) after each session (i.e., six times in total). After participating in the PLC sessions, teachers in both groups completed the third round P-TABS survey and the Post-PLC Teacher Survey.

Workshop. Seven teachers participated in a workshop entitled, "Exploring Force and Motion through Ramps and Pathways" on Saturday, January 30th, 2016 for 3 hours at the University of Nebraska-Lincoln (www.uni.edu/coe/special-programs/regents-center-early-developmental-education/ceestem/presentations/ramps-and-pathwa). One teacher was not able to attend the workshop due to a family emergency. This teacher did not make up training but was included for further participation. The workshop was organized and provided by the Regents' Center for Early Developmental Education at the University of Northern Iowa. The presenter came from Cedar Falls, Iowa to visit the participating teachers in Lincoln.

The Ramps and Pathways curriculum is considered to have special value for children's science learning because it includes activities designed to respect children's preconceptions and naïve ideas and promote their deep reasoning about scientific phenomena (DeVries & Sales, 2011). The workshop provided the teachers with an opportunity to experience various physical science activities in which teachers tend to express more discomfort teaching in comparison to life and earth science (Harlen & Holroyd, 1997; Kallery & Psillos, 2001; Maier et al., 2013; Olgan, 2015; Saçkes, Trundle, Bell, & O'Connell, 2011). The purpose of the workshop was to support teachers in understanding how to foster young children's learning about physical science concepts and scientific inquiry, which results in children learning about the concepts of forces and motion, developing positive attitudes about science, and engaging children in scientific inquiry and engineering-related problem solving. During the workshop, teachers watched videos of children using physical science materials (e.g., physics in early childhood and elementary classrooms: a constructive approach, Ramps and Pathways: integrated STEM), experimented with the materials themselves, and learned how to use the materials in their own teaching.

PLC sessions. Structural and procedural components for face-to-face and online PLC sessions were developed for this study (see Table 3.1 and Table 3.2 for detailed information). In total, six sessions were conducted. However, each session was not pre-planned, but it was fluid and evolving. A primary investigator facilitated both face-to-face and online PLC sessions. In session one conducted 2 weeks after the workshop, the facilitator provided an overview of PLC sessions, where teachers introduced themselves to one another and picked a session for which each would be the discussion leader. The facilitator and the teachers shared their experiences with and reflections on the Ramps and Pathways workshop. In each session, teachers developed a lesson plan and received feedback from other teachers. The teachers also reflected on their lesson plans (e.g., what worked, what didn't, challenges) after they implemented science activities in the classroom. In each session, the facilitator presented an emergent content/topic based on teachers' needs and children's interests, and one teacher presented her own topic related to their science teaching practices (flexible and open) and led the group for a reflective discussion. The discussion leader (i.e., one teacher in each session) was asked to present any knowledge, skills, strategies, or practices that they would like to share with others, prepare discussion questions, and lead the group for reflective discussions for about 20 minutes. The topics of the presentation and discussion were relevant to the overall topics discussed in PLC sessions (i.e., early childhood physical science, science teaching and learning).

Table 3.1

PLC Types, Session Lengths, and Data Sources

PLC Type	Session Length	Data Sources
Face-to-Face	1.5 (sessions 1 & 6) to 2 hours (sessions 2-5)	Audiotaped discussions; Field notes by facilitator; Artifacts (lesson plans, reflective writings, activity sheets, photos, notes)
Online	2 weeks; Asynchronous	Archive files (online postings); Facilitator's notes about the online communications; Artifacts (lesson plans, reflective writings, activity sheets, photos, notes)

Table 3.2

PLC Session Content Description

Session	Content	Material/*Article	Activity
Session 1	PD; PLC; Ramps and Pathways; Early Childhood Science Education	Session overview; Discussion leader sign-up sheet; Science process words; Lesson plan example; Information packet about science teaching; Documentation annotation * Zan, B., & Geiken, R. (2010). Ramps and pathways: Developmentally appropriate, intellectually rigorous, and fun physical science. *YC Young Children*, *65*(1), 12.	<Self-introduction> Shall we introduce ourselves? <Workshop Reflection> Do you have any ideas, thoughts, or questions from the Ramps and Pathways workshop? <Discussion> How can we solve the barriers identified to implement the Ramps and Pathways activities? Do you have any challenges or needs to do science activities with kids? What support would you need? What would you expect from this group? What would you like to take away from the sessions? What would you like to discuss in this group?
Session 2	Physical	Physical science: teacher's guide; List of	<Discussion>

	Science Education (e.g., content, books, activities); Teacher's Interventions; Children's Science Learning	physical science books; Productive questions; Information packet about physical science education; Children's science learning; Science guidelines/standards; NE Early Learning Guidelines; Teaching Strategies GOLD; Lesson plan sheet *Edmiaston, R., & DeVries, R. A Pilot Study of Young Children's Construction of Ramps and Pathways. * Van Meeteren, B., & Zan, B. (2010). Revealing the work of young engineers in early childhood education. In *Collected Papers From the SEED (STEM in Early Education and Development) Conference, http://ecrp. uiuc. edu/beyond/seed/zan. html*. * McEntire, N. (2011). ECAP Report: Encouraging Scientific Thinking in Preschoolers. *Childhood Education*, *87*(3), 217-218. *Kato, T., & Van Meeteren, B. D. (2008). Teaching Strategies: Physical Science in Constructivist Early Childhood Classrooms. *Childhood Education*, *84*(4), 234-236.	Can you share any 2 ideas that interested you and why from the articles? <Productive Questions> There are 6 types of productive questions that promote children's science learning (Handout). Can you think of any productive questions? <Lesson Plan Development>
Session 3	Promoting Children's Inquiry Skills and Science Learning	A checklist for the block center; Resources for science in the early years; Lesson plan sheet * Saçkes, M., Trundle, K. C., & Flevares, L. M. (2009). Using Children's books to teach inquiry skills. *YC Young Children*, *64*(6), 24. * Lindeman, K. W., & Anderson, E. M. (2015). Using Blocks to Develop 21st Century Skills. *YC Young Children*, *70*(1), 36. *Van Meeteren, B. (2015). Engineering in Preschool? The Children Are Already Working on That! *Teaching Young Children, 8*(3), 30-31 * Roseno, A., Geist, E., Carraway-Stage, V., & Duffrin, M. W. (2015). Exploring Sunflower Seeds: A Thematic Approach to Science Inquiry. *YC Young Children*, *70*(3), 88. * Hoisington, C., Chalufour, I., Winokur, J., & Clark-Chiarelli, N. (2014). Promoting Children's Science Inquiry and Learning Through Water Investigations. *YC Young Children*, *69*(4), 72.	<Discussion> Does your block center promote 1) creativity, 2) communication, 3) critical thinking, and 4) collaboration? <Lesson Plan Development>

Session 4	Various Science Activities (e.g., physical science, life science, earth/space science)	Open-ended questions; List of science activities; Building language and scientific literacy; Lesson plan sheet *Sherwood, E. A., & Freshwater, A. Early Learning Standards in Action. *Blake, S. (2009). Engage, investigate, and report: Enhancing the curriculum with scientific inquiry. *YC Young Children*, *64*(6), 49. *Erdman, S., & Downing, M. (2015). The Science of Superheroes. *Teaching Young Children, 8*(3), 24-27 *Bosse, S., Jacobs, G., & Anderson, T. L. (2009). Science in the air. *YC Young Children*, *64*(6), 10. *Patrick, H., Mantzicopoulos, P., & Samarapungavan, A. (2009). Reading, writing, and conducting inquiry about science in kindergarten. *YC Young Children*, *64*(6), 32. *Brenneman, K. (2009). Let's find out! Preschoolers as Scientific Explorers. *YC Young Children*, *64*(6), 54.	<Asking Open-ended Questions> Choose one activity/center/area in your classroom. Can you list any open-ended questions you can use? <Discussion> How can we talk about science with children? How can we promote children's writing about science? <Lesson Plan Development>
Session 5	5E Instruction (i.e., engage, explore, explain, extend, & evaluate)	The e5 instructional model; Constructivism and the five e's; 5E learning sequence; Science teaching resources; Science activity sheet; Lesson plan sheet	<Intentional Teaching> What is children's interest? Based on children's interest, think about intentional teaching. How can we set it up? How can we talk about it with children? <Lesson Plan Development>
Session 6	Reflection on PLC Sessions	Lesson plan sheet	<Lesson Plan Development> <Reflection> Can you provide any feedback about this PLC group (e.g., thoughts, challenges, suggestions, etc.)?

Face-to-face PLC sessions were held twice a month for about two hours in a designated conference room at one of the participating centers for three months (i.e., 6 biweekly sessions; 11 hours in total). Research indicates that duration is an important factor in Professional Development (PD) (Darling-Hammond & Richardson, 2009; Hong et al., 2013; Snell et al., 2013; Yoon, Duncan, Lee, Scarloss, & Shapley, 2007) and suggests that PD includes at least 14 hours of learning to be effective and influence practices. Online PLC session guidelines and materials were uploaded twice a month by the facilitator, and teachers were encouraged to participate in discussions on a Facebook page created for this research project. The same set of session materials was used for each PLC session for both groups. For interactive online PLC sessions, Google Docs and Box links with resources were shared on the Facebook page in the same sequence as that used for face-to-face PLC sessions. Teachers participating in online PLC sessions were reminded about the privacy and the confidentiality issues regarding the information and the images shared on the Facebook page, Google Docs and Box, and the researcher followed the guidelines provided by the University Institutional Review Board (IRB).

The facilitator stayed neutral and had no decision-making authority, but intervened on group process and structure when needed (Schwarz, 2002). In this study, for both face-to-face and online groups, the facilitator played pedagogical, social, and managerial roles. The pedagogical role included providing collaborative tasks, promoting critical thinking and research skills, probing, asking questions, providing feedback and instruction, facilitating active discussion, synthesizing teachers' comments, and referring to experts or outside resources in the field. The social role included setting a positive tone, keeping the communication flowing, encouraging interpersonal communication, and providing warm support. The managerial role included designing, organizing, coordinating, and overseeing the logistics of the group activities and the materials shared by the group (Maor, 2003; Palloff & Pratt, 1999).

Compensation. Each teacher received incentives for participation. Incentives included one children's book on science, a book, titled "*Ramps and Pathways: A Constructivist Approach to Physics with Young Children*," and a $120 Walmart gift certificate per teacher. Teachers also received a certificate of completion for the workshop that counts towards state-mandated child care training hours.

Participants

Participants included eight female early childhood teachers from NAEYC-accredited child care centers in a mid-sized, Midwestern city. Eight teachers were considered an appropriate number of sample size for this research that used an in-depth case study design (Gerdes, 2012; Hollins, McIntyre, DeBose, Hollins, & Towner, 2004). The participants were from five different centers and seven different classrooms. All of the participants in this study were Caucasians serving 3- to 5-year-old children. I assigned participants pseudonyms to protect their confidentiality. Teachers by center were randomly assigned to two groups (i.e., 4 teachers in face-to-face; 4 teachers in online PLC group; see Table 3.3). Centers were randomly assigned to one of the two groups through drawing. The face-to-face PLC centers were drawn first and then the rest became the online PLC centers automatically. The group size of four teachers was considered an appropriate number for building and developing a PLC (Bray, 2000; Cunningham et al., 2015; Lee, 2010). One group, Cloy, Megan, Emily, and Joy, participated in the face-to-face PLC sessions. The other group, Kate, Kelly, Lilly, and Betty, participated in the online PLC sessions. Participating teachers' education and years of early childhood experience were different. Megan, Emily, and Joy each had a master's degree in Child Development/ Early Childhood, Education, or Early Childhood Education. Cloy, Lilly, and Betty each had a bachelor's degree in Psychology, Elementary Education, or Early Childhood and Elementary Education. Kate and Kelly each had a Child Development Associate (CDA) credential in Early Childhood Education. Emily and Joy were master teachers in the classroom. All other teachers were lead teachers in the classroom. Joy, Kate, and Kelly had more than 10 years of early childhood experience. Megan and Emily had 6-7 years of early childhood teaching experience. Cloy, Lilly, and Betty had 1-2 years of early childhood teaching experience. Megan and Joy had an early childhood teaching certificate. Betty had both a CDA and an early childhood teaching certificate.

Table 3.3

Characteristics of Participants (N = 8)

Participant	PLC Type	Center (Class)	Education	Position Title	Years of EC Experience	CDA	EC Teaching Certificate
Cloy	F2F	1 (1)	Bachelor	Lead Teacher	1	No	No
Megan	F2F	2 (2)	Master's	Lead Teacher	6	No	Yes
Emily	F2F	2 (2)	Master's	Master Teacher	7	No	No
Joy	F2F	2 (3)	Master's	Master Teacher	12	No	Yes
Kate	Online	3 (4)	CDA	Lead Teacher	11	Yes	No
Kelly	Online	4 (5)	CDA	Lead Teacher	10	Yes	No
Lilly	Online	5 (6)	Bachelor	Lead Teacher	2	No	No
Betty	Online	5 (7)	Bachelor	Lead Teacher	1	Yes	Yes

Table 3.4 shows characteristics of classrooms of participants. Five teachers used Teaching Strategies GOLD/ Creative Curriculum, two teachers used High/ Scope, and one teacher used a mix of child led and teacher led in the classroom. All teachers except Lilly had a science center or area in their classrooms and they listed various science materials and activities in their science areas. Five teachers reported that they provided science activities every day.

Table 3.4

Characteristics of Classrooms of Participants (N = 8)

Participant	Curricular Approach Used	Science Area/ Center	Frequency of Science Activities
Cloy	Creative Curriculum/ Teaching Strategies GOLD	Yes	Daily
Megan	Creative Curriculum/ Teaching Strategies GOLD	Yes	Daily
Emily	Creative Curriculum/ Teaching Strategies GOLD	Yes	Daily
Joy	Creative Curriculum/ Teaching Strategies GOLD	Yes	Daily
Kate	Mix of Child Led & Teacher Led	Yes	Daily
Kelly	Creative Curriculum/ Teaching Strategies GOLD	Yes	Twice a Week
Lilly	High/ Scope	No	Once a Week
Betty	High/ Scope	Yes	Daily

Measure and Data Sources

Teacher demographic information. To measure teachers' demographic information, the Teacher Demographic Survey (see Appendix A for detailed information) was used. The survey questions included information about teachers' position title, early childhood teaching experience, curricular approaches, science-related training experience, ethnicity, and education. Teachers were also asked to report about the science materials and experiences that they provided in their classrooms.

Teacher attitudes, beliefs, and perceptions. To measure this construct, the Preschool Teachers' Attitudes and Behaviors towards Science (P-TABS) scale was used (Maier et al., 2013). The P-TABS identifies three factors that influence teacher instruction and child outcomes: 1) *teacher comfort*, 2) *child benefit*, and 3) *challenges*. The first factor, *teacher comfort*, consists of 14 items and measures teachers' comfort with planning and implementing different science activities (e.g., "*I feel comfortable doing science activities in my early childhood classroom*"*)*. The second factor, *child benefit*, consists of 10 items and measures teachers' perception about how science improves young children's science learning and learning in other areas (e.g., "*Preschool science activities help foster children's interest in science in later grades*"). The third factor, *challenges*, consists of 7 items and measures the level of teachers' discomfort with their lack of science knowledge, science teaching ability, and preparation time (e.g., "*Preparation for science teaching takes more time than other subject areas*") (see Appendix E). Teachers were asked to indicate how much they agreed with each statement using a 5-point scale (strongly disagree = 1, strongly agree = 5). Maier et al. (2013) shows evidence for a concurrent and predictive validity and a reliability of the P-TABS as a measure for preschool teachers' attitudes and beliefs about science teaching (Maier et al., 2013). The P-TABS scores were statistically sensitive to a science intervention and were associated with observed instructional practices. The overall internal consistency of the P-TABS was high (Cronbach's alpha = .91), and the internal consistencies for the three factors (teacher comfort, child benefit, and challenges) ranged from .71 to .89 in the original research (Maier et al., 2013), which shows the reliability of this measure. The total score for each subscale was calculated by dividing the sum of each subscale scores by the number of items (possible range = 1 - 5). Teachers completed the P-TABS three times (i.e., before the workshop, in-between the workshop and the PLC sessions, and after the PLC sessions) (see Appendix B).

Teacher dialogue/postings. Teacher dialogue was recorded in both face-to-face and online PLC sessions. During each face-to-face PLC session, teachers' conversations were audiotaped, and after each session, audio recordings were transcribed and coded for emerging themes. In total, six audio files (i.e., one from each session) were collected. During each online PLC session, teachers' written interactions and postings were archived and compiled, and after each session, archives were coded for emerging themes. In total, six archive files (i.e., one in each session) were collected.

Artifacts. During each session, artifacts such as teachers' lesson plans, reflective writings (e.g., how to talk about science with kids, how to set up science areas, how to develop 5E instruction), activity sheets (e.g., 6 types of productive questions, open-ended questions), notes, and documentation (photos, videos, panel) during the PLC sessions were collected. During sessions two through six, teachers were asked to develop lesson plans for science activities. Based on teachers' preference, the group either worked together or worked individually for the lesson plan development. When teachers developed lesson plans individually, they then shared and discussed their plans as a group. Teachers were also asked to complete reflective writings and activity sheets related to science learning and teaching during the sessions. During session two, teachers were asked to generate 6 types of productive questions (i.e., attention-focusing, measuring and counting, comparison, action, problem-solving, and reasoning questions) that can promote children's science learning during the Ramp and Pathways activities. During session three, teachers completed a checklist for their block area to see if it promotes children's creativity, communication, critical thinking, and collaboration. During session four, each teacher engaged in brainstorming about open-ended questions that can be used in the classroom to improve children's science learning. During session five, teachers developed their ideas about how to talk about science with their children and how to set up the science center in their classroom. During session six, teachers developed the 5E instruction plan (i.e., Engage, Explore, Explain, Extend, and Evaluate).

Facilitator notes. During both face-to-face and online PLC sessions, the facilitator recorded notes. While the teachers were participating in the sessions (face-to-face or online), the facilitator made notes about each teacher's participation and PLC session atmosphere (e.g., "*(Face-to-face group) teachers were excited about participating in PLC,*" "*A lot of in-depth conversations happened*," "*(Online group) teachers were quiet*," etc.).

Survey about online participation context. After each session, the teachers who participated in the online PLC sessions completed a short online survey asking questions about their online participation contexts. There were four questions: 1) "*When did you log into the online PLC sessions?*" 2) "*Where did you log into the online PLC sessions?*" 3) "*What work did you do during the online PLC sessions?"* and 4) "*How long, in total, did you stay logged in and participate in the online PLC sessions?"* (see Appendix C for detailed information). In total, six surveys were collected (i.e., one after each session).

Teacher survey about PLC experience. After all PLC sessions were ended, teachers completed a survey of open-ended questions about their experiences with the PLC (see Appendix D). The questions were about the changes, benefits, challenges, and suggestions of participating in the face-to-face PLC or online PLC. This qualitative data provided in-depth information to understand the experiences and perspectives of PLC participants (e.g., "*how have you changed after participating in this PLC group?*" "*How can the PLC sessions be improved?*"). In order to validate findings from participants' responses, a member checking strategy was used (Clark & Creswell, 2014). Following the data analysis, participants were contacted through email, and 38% of them (i.e., 3 of 8 participants, 2 from face-to-face and 1 from online PLC group) verified the accuracy of the results.

Data Analysis

Both qualitative and quantitative means of data collection and analyses were used to answer the research questions. For research questions 1 and 2, a thematic approach was used in order to describe the multiple themes during the PLC sessions (Clark & Creswell, 2014). Additional data sources such as teacher artifacts and investigator notes were collected during the PLC sessions and triangulated in order to support themes (Clark & Creswell, 2014).

Qualitative data analysis process includes preparing the data for analysis, exploring the data, coding the data, developing themes, and validating the credibility of the findings (Clark & Creswell, 2014). Teachers' conversations during the face-to-face PLC sessions and teachers' postings during the online PLC sessions were the primary qualitative data for this study. Teachers' audio files during the face-to-face sessions and archive files during the online sessions were transcribed and coded to develop description and themes. The MAXQDA 11 software program was used for these qualitative analyses. Each transcript was read numerous times to develop initial emergent themes. This was an inductive process using four stages of analysis: 1) the data were read for a general sense, 2) codes were assigned (e.g., this stage started with many initial codes), 3) codes were reduced and refined (e.g., similar codes were grouped together and redundant codes were collapsed), and 4) codes were grouped into themes (e.g., similar codes were grouped together and aggregated to build themes). The initial emergent themes by the researcher were compared to a colleague's initial emergent themes from 33% of the data. Through discussions and coding review with the colleague, themes were collapsed and merged. Final themes were established through the continued and iterative analysis of the data.

In order to validate findings from the qualitative data collected during the face-to-face and online PLC sessions, a triangulation strategy was used (Clark & Creswell, 2014). Multiple sources of data, notes by the facilitator and artifacts (e.g., lesson plans, reflective writings, activity sheets, notes, documentation, etc.) by the teachers during the PLC sessions, were collected after each session and incorporated as part of the triangulation process. Teachers' lesson plans, reflective writings, activity sheets, notes, and documentation and the facilitator's notes were examined and used to corroborate emergent themes from the primary data. Additionally, findings were checked with a colleague (i.e., colleague check) to strengthen validity. Another strategy, member checking, was used to ensure the accuracy and credibility of the results (Clark & Creswell, 2014). Three out of 8 teachers (i.e., 38 % of the teachers) participated in the member-checking process, and all of them verified that the findings were accurate. Finally, rich descriptions were used to interpret findings and provide readers with an in-depth picture of information about what was happening during the PLC sessions.

Different findings may be produced if the qualitative research is replicated. Findings from qualitative research can be subjective and different depending on the researcher's perspectives and interpretations (Clark & Creswell, 2014). In this sense, multiple findings tend to be acceptable in qualitative research. This study was planned, conducted, and analyzed appropriately with in-depth and careful decisions to maximize reliability.

For research questions 3 and 4, quantitative data were collected through the P-TABS questionnaire (Maier et al., 2013). A series of paired –samples *t*-tests were used to compare pre-test scores (before the workshop) to in-between-test scores (in-between the workshop and the PLC sessions), in-between-test scores (in-between the workshop and the PLC sessions) to post-test scores (after the PLC sessions), and pre-test scores (before the workshop) to post-test scores (after the PLC sessions) on the P-TABS. This analysis showed the changes in teachers' attitudes and beliefs toward science teaching after the workshop, after the PLCs, and after the combination of workshop and PLCs (i.e., face-to-face or online). SPSS version 23 was used for these quantitative analyses. While these results are informative about the two groups (i.e., face-to-face and online) of teachers, they should be interpreted with caution because results from such small groups of participants are not generalizable to a larger population. The P-TABS results were used to present the general trend of the data across the three time points rather than to show statistical changes (see Figure 4.13 for information).

For research questions 5 and 6, qualitative data were collected through open-ended survey questions (see Appendix D). The data were thematically analyzed in order to understand what changes, benefits, challenges, and suggestions teachers perceived as they participated in face-to-face or online PLC sessions. The participants' responses were examined to discover codes using an iterative process, and then the codes were grouped into categories. A qualitative approach is considered appropriate to explore topics and hear the participants' voices (Creswell, 2012; Knoche, Kuhn, & Eum, 2013).

CHAPTER 4

FINDINGS

Results

Emerging Themes from Face-to-face PLC Sessions

For research question 1, the teachers' dialogue during the face-to-face PLC sessions were audiotaped, transcribed, and analyzed for emerging themes. Four main themes and 13 subthemes emanated from the iterative analyses of the face-to-face sessions. The themes included collaborating with other teachers, inquiring about science teaching and learning, reflecting on child learning and teachers' own practice, and creating positive climate (see Table 4.1 for detailed information).

Table 4.1

Definition and Examples of the Themes and Subthemes during the Face-to-face PLC

Theme	Subthemes	Definition	Examples/ Quotes
1. Collaboration	1a. Cooperative lesson planning	The action of working together to create a lesson plan	*Creating science lesson plans cooperatively*
	1b. Providing feedback	The action of cooperating by commenting, supporting, or suggesting other teachers' sharing	*"Wow, that's impressive;" "Kids would love that;" "How about we use water to move found objects?"*
	1c. Sharing ideas and practices	The action of collaborating by sharing ideas, strategies, and practices	*Sharing how the ramps activities worked in the classroom; Sharing teaching ideas or practices*
	1d. Sharing documentation about child learning	The action of collaborating by sharing documentation about children's talk, behavior, reasoning, work, or learning	*e.g., Pictures; videos; notes; panels*
2. Inquiry about Science Teaching and Learning	2a. Problem-solving	The action of finding solutions to problems; Defining the challenge; Generating alternatives	*Defining the challenge when implementing ramps activities and explaining science concepts; Generating alternatives and finding solutions to the challenge*
	2b. Raising questions about science teaching and learning	A seeking of information by asking questions; Inquiring about child learning, teacher teaching, and science teaching	*Inquiring about child talk, development, behavior, interests, intention, problem-solving, outcome; Inquiring about teacher plan, intention, documentation, challenges; Inquiring about science activities, materials, concepts, etc.*
	2c. Evaluating science teaching and learning	The action of making a judgment about science teaching, child learning, or teacher teaching	*Evaluating how the ramps and pathways activities worked in the classroom; Evaluating children's understanding, reasoning, talk, and behavior; Evaluating teachers' teaching*
3. Reflection	3a. Revisiting the Ramps and Pathways	The action of thinking, examining, or discussing the Ramps and Pathways	*"When we went to the Saturday professional development, she said*

Theme	Subthemes	Definition	Examples/ Quotes
	workshop	workshop again	*something about this is gravity and um one of the things I thought was that could be a word introduce to our kids. And then I remember her suggestion was don't use that word yet."*
	3b. Revisiting science materials and activities	The action of thinking, examining, or discussing previous science teaching materials, activities, and experiences again	*"… Um so we had a student teacher set this up in the block areas away to get them to start using it and in a different way? With this big boat and these as slides and these blocks have pictures of teachers and children on them. And so Haley started using it and she took this little blue wood guy and was just dropping down the side? (laugh)"*
	3c. Reflecting on teacher own practice	The action of expressing opinions, ideas, or beliefs on teachers' own teaching practices, which was thought carefully	*"Um I put out materials, change of the materials that are there. Ask them questions about why they're doing things and I don't know I might be going too far. Too far ahead."*
	3d. Reflecting on child work and child learning	The action of expressing opinions, ideas, or beliefs on children's own learning and work, which was thought carefully	*"Um so this is Camden… He's regular go to the builder. Um highly intelligent um creative whatever, but it was very interesting because he came over and he started flat surface. Just pushing the marble back and forth. Wow not what I expected from you. And then I put some pool over there. And then he just drop the marble through the pool noodle (laugh)"*
4. Positive Climate	4a. Expressing positive emotions	An emotional response that is pleasant, joyful, and happy	*Laughing; smiling*
	4b. Showing excitement	An emotional response that includes great enthusiasm and eagerness, and interest	*"I am excited (laugh);" "I'm really interested to see."*

Theme 1: Collaboration. During the face-to-face PLC sessions, the teachers worked collaboratively by planning science lessons together, providing feedback, and sharing their ideas, practices, and documentation. Throughout the face-to-face sessions, the teachers planned science lessons cooperatively. The following is one of the examples of collaborative planning during session three (see Figure 4.1 for the developed lesson plan). In this example, teachers were writing objectives for a science activity together while sharing ways to introduce new materials and content to young children and selecting strategies to prompt children's thinking.

Megan: "*Teacher will introduce content…*"
Joy: (writing) "*Okay. So we just defined the contents.*"
Emily: "*So…*"
Joy: "*Now it's like do it whatever?*"
Emily: "*Yeah. Now with objective two - bring in the water?*"
Joy: "*Transfer the water.*"
Emily: "*So teacher can bring with the hose and… maybe she asks some open-ended questions or?*"
Megan: "*Yeah.*"

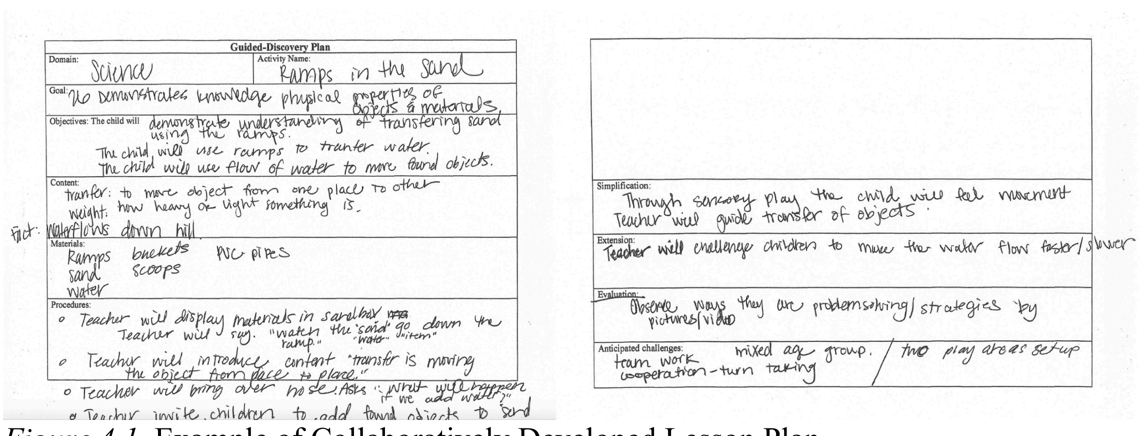

Guided-Discovery Plan
Domain: Science
Activity Name: Ramps in the sand
Goal: 26 Demonstrates knowledge physical properties of objects & materials.
Objectives: The child will demonstrate understanding of transfering sand using the ramps.
The child will use ramps to tranfer water.
The child will use flow of water to more found objects.
Content:
tranfer: to more object from one place to other
weight: how heavy or light something is.
Fact: water flows down hill
Materials:
Ramps, buekets, PVC pipes
sand, scoops
water
Procedures:
○ Teacher will display materials in sandbox. Teacher will say. "watch the 'sand' 'water' 'item' go down the ramp."
○ Teacher will introduce content "transfer is moving the object from place to place."
○ Teacher will bring over hose. Asks: "What will happen if we add water?"
○ Teacher invite children to add found objects to sand
Simplification: Through sensory play the child will feel movement. Teacher will guide transfer of objects.
Extension: Teacher will challenge children to move the water flow faster/slower
Evaluation: Observe ways they are problemsolving/strategies by pictures/video
Anticipated challenges: team work, cooperation - turn taking / mixed age group. / two play areas setup

Figure 4.1. Example of Collaboratively Developed Lesson Plan

Throughout the PLC sessions, all teachers supported one another by providing constructive feedback. The teachers acknowledged each other's ideas by commenting, "*Wow, that's impressive*," "*Kids would love that*," "*I loved that you put it in the sand table*," and "*That's great*." They also provided many suggestions and added new ideas. When they were developing a lesson plan collaboratively, Joy suggested using water saying, "*How about we use water to move found objects?*" and Emily suggested adding buckets saying, "*Could we even add um buckets? Because that's something our kids seem to do… they like have something at the end to collect the item*."

When Joy was the discussion leader of the group, she handed out copies of her notes that included information about what she observed and documented during the Ramps and Pathways activities in her classroom (e.g., what children did, what they said, how they interacted with the materials, what role the teacher played in the interactions, etc.) (see Figure 4.2). She also shared strategies she used to present the Ramps and Pathways materials to the children in a way that would elicit children's thinking (i.e., providing materials that are not round; not laying materials in an incline), which was consistent with Piaget's constructivist view (i.e., children as active learners who construct their understanding by interacting with their physical environment; and providing situations where cognitive conflict is likely to happen is a role teachers can play to promote children's cognitive learning and development):

> "*Here is some note I have. So um I had kind of series of four examples that I want to share with you today. And just to kind of give you an overview of how we presented um the materials to the children. So we have had ramps just like these in our classroom several times (by showing some pictures)… And they view marbles on those. They view rocks oh not rocks round things, cars, and what they knew about the ramps. And so when I presented last week these materials I*

wanted to present things that were not necessarily round. And so we had just a little builder table in our block area. So I just set them there, I didn't even lay them at an incline anything. I literally put them I knew that they knew already how to set up and everything. Um and so there are lots of examples children doing what they know put it at the top. Put them together so they work and roll down but there were few problems that you know came I will show you a few videos of that."

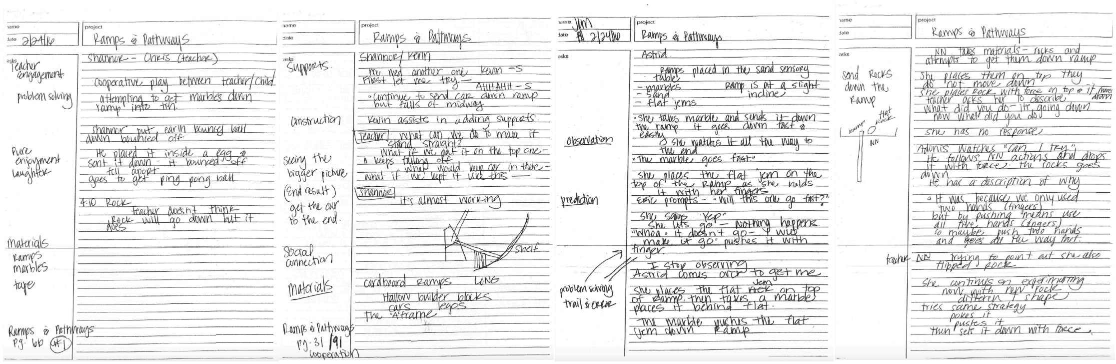


Figure 4.2. Joy's Notes Shared with Other Teachers

Joy also shared her documentation about children's learning that included photos and videos of children. The videos and the documentation panel demonstrated the process of children's reasoning and examples of their conversations and behavior during the Ramps and Pathways activities. Figure 4.3 shows the panel Joy made and displayed in her center.

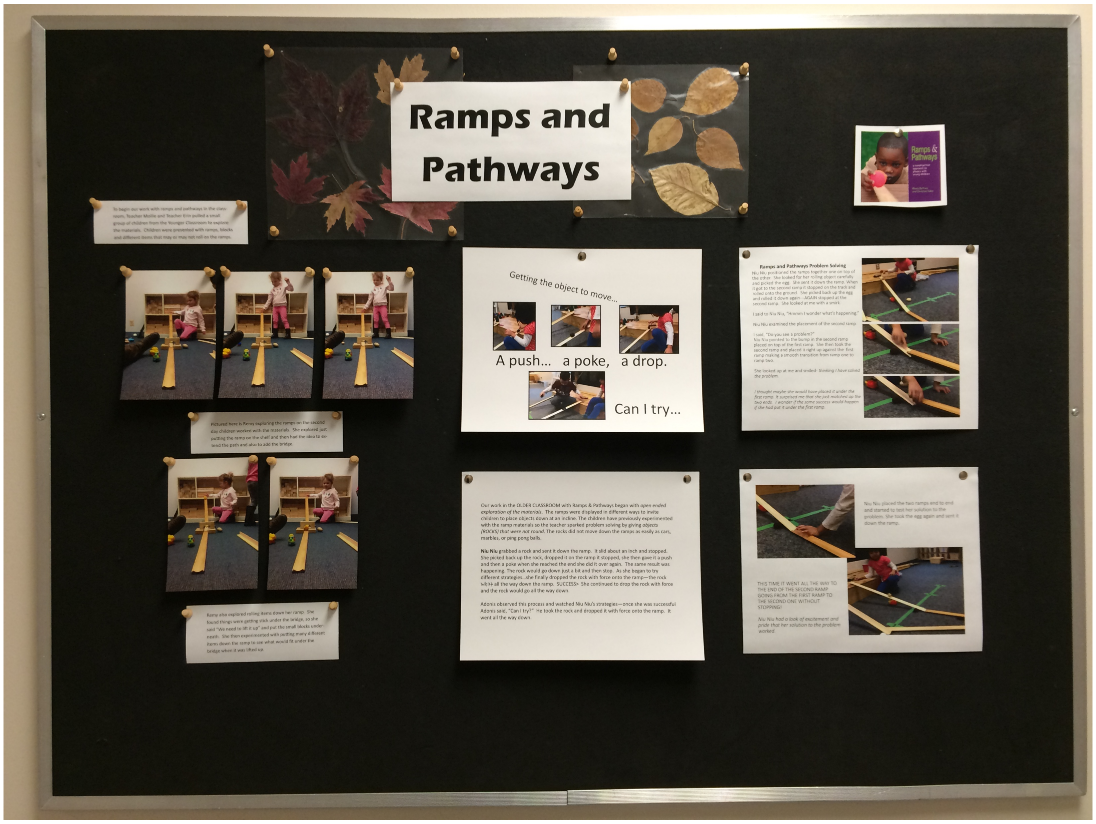


Figure 4.3. Documentation Panel Made and Displayed by Joy

In sum, through the face-to-face PLC meetings, the teachers had many opportunities to work collaboratively. They planned science lessons together. They provided one another with constructive feedback about their ideas and practices. They also shared their documentation about how children interacted with the Ramps and Pathways materials. The field notes by the facilitator, "*The discussion leader, Joy, shared how Ramps activities worked in her classroom and showed some pictures and videos of children exploring Ramps materials. Lots of collaboration and sharing. She shared her documentation notes with others*" also corroborated the theme, *Collaboration*.

Theme 2: Inquiry about Science Teaching and Learning. During the face-to-face PLC sessions, the teachers expressed and articulated their challenges in teaching science to young children and generated alternatives and solutions to those challenges.

The teachers also raised questions about their science teaching as well as children's science learning and evaluated their practices. Teachers were constantly engaged in the problem-solving process by defining challenges in teaching science, brainstorming solutions and new strategies, and planning for the new solutions they can implement in their own classroom. When Joy expressed her challenge in using one component (Explain) of the 5E instruction model (e.g., Engage, Explore, Explain, Extend, and Evaluate), another teacher, Emily, shared one solution:

> "*When we went to the Saturday professional development, she said something about this is gravity and um one of the things I thought was that could be a word introduced to our kids. And then I remember her suggestion was don't use that word yet. Let them use that. So I think even I mean I don't know this is true but within this box maybe there's even progression within that let them explain it and then the third one down then provide it formally after they have some bases to scaffold it on?*"

Artifacts collected during the problem-solving process included activity sheets completed by teachers regarding open-ended questions (see Figure 4.4) and productive questions (see Figure 4.5). Teachers brainstormed strategies to engage children in scientific problem-solving skills and science talk by writing down examples of open-ended questions (e.g., *what happened when you dumped them in the water? why did it work that way?*) and also by creating questions that are likely to promote children's science learning (i.e., attention-focusing, measuring and counting, comparison, action, problem-solving and reasoning questions). Teachers were engaged in these conversations as a way of resolving challenges they experience in teaching young children science and scientific thinking skills.

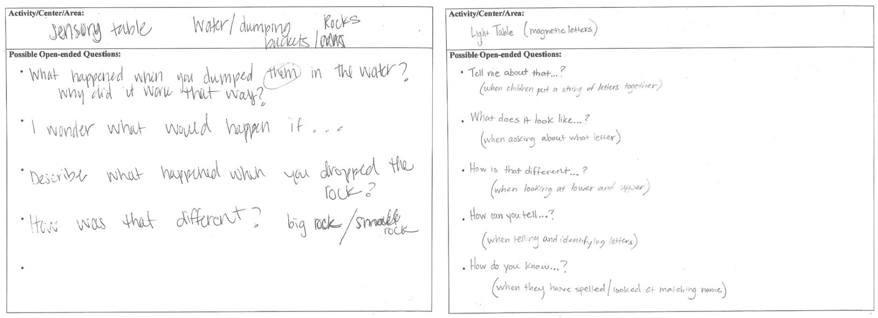


Figure 4.4. Open-ended Questions Completed by Teachers

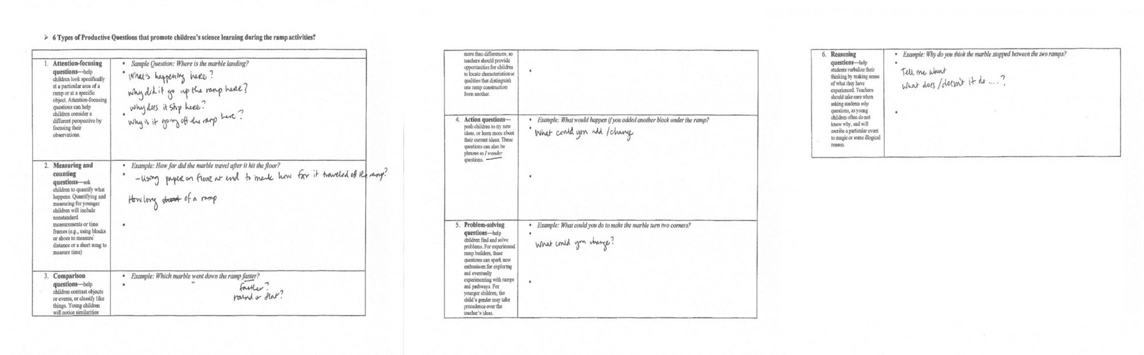


Figure 4.5. Six Types of Productive Questions Completed by Teachers

When Joy was the discussion leader, she raised a question about how they could present the science materials to children with inquiry about children's science learning:

> "*They (children) were beginning to just understand how the ramps kind of go together. And then they (children) just discovered the support system for that. Um but the piece of that of Scott and Kay was how it talks about in those 10 principles that um uninterrupted exploration kind of needs to happen for them to construct their mental relationships with materials. And I loved that phrase, construct their mental relationship with the materials. How cool is that? Um so what are you guys' thoughts as far as materials? And how we um presented it to children? Because we didn't set it up for them.*"

This quote illustrates that the teacher, Joy, was inquiring about teachers' intervention based on children's understanding of the Ramps materials and children's learning (e.g., children construct their mental relationships with the materials with uninterrupted exploration).

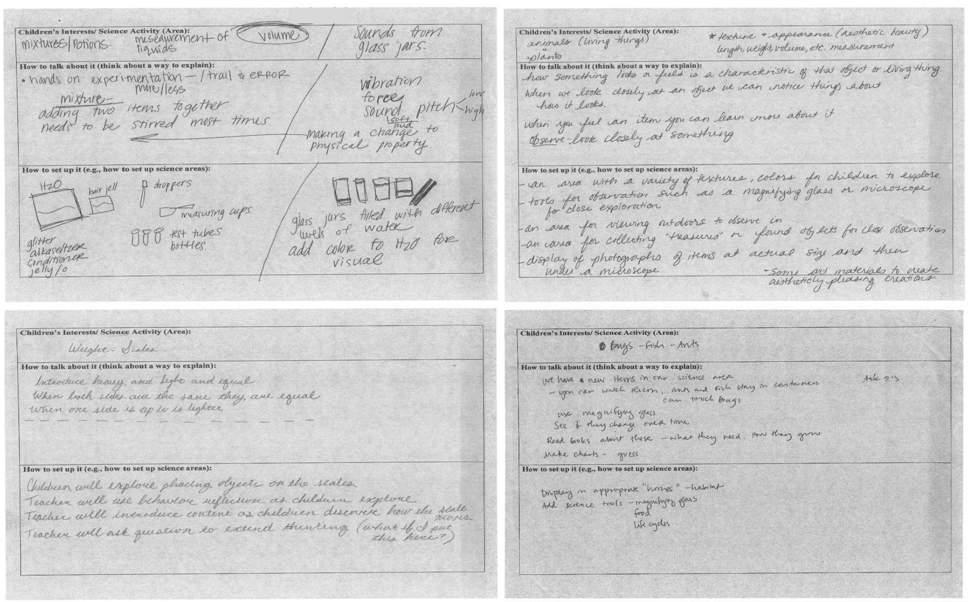


Figure 4.6. Science Teaching Ideas Developed by Teachers (see Appendix F for larger images)

During the sessions, the teachers also inquired about science teaching and developed their ideas about how to talk about science with children and how to set up the science center in the classroom (see Figure 4.6; see Appendix F for larger images). Joy developed two ideas (i.e., mixtures and potions, sounds and pitches) that go with water. She inquired about incorporating exploration and discovery into children's play by bringing in the content of 'more' or 'less' and identifying what mixture is. She talked about making potions with water to talk about volume (e.g., how much of liquid do we need?) and brainstormed science materials such as hair jell, glitter, Alka-Seltzer, conditioner, jelly, droppers, measuring cups, test tubes, and bottles. She also talked about connecting the concept of ‘volume’ to the sounds that glass jars made by filling the jars with different amount of water and adding color for the visual of the water. Emily developed her ideas about examining textures and appearances of various objects and introducing the word “observe” to her children using science tools such as magnifying glass and microscope. Megan developed her ideas about offering a variety of materials with scales to introduce the concept of ‘weight’ to her children. Cloy developed her ideas about introducing new items such as bugs, fish, and ants in their science area, asking questions about what they are and where they lived, and adding science tools/materials such as magnifying glass, books, charts, food, and life cycles.

When Emily was the discussion leader in session three, she shared pictures and videos with other teachers and made an assessment about the children’s understanding of scientific concepts (e.g., physical science such as forces affecting motion and speed) and process (e.g., observing, exploring, and testing) during the Ramps and Pathways activities:

> “*Initially what they care about was what objects go down it um I think in this case they were trying to see what made the corner what would actually go down the ramp into the next one but I think they found joy in that. There were some of action when he was doubling them up and putting two at a time*.”

This quote illustrates teacher’s evaluation and inquiry about children’s understanding, reasoning, intention, and behavior. In this quote, the teacher focuses on the process of children’s scientific problem-solving that involves exploring the movement of objects and making experiments of different ideas while figuring out what their intentions were. In addition, the teacher was noticing the development of children’s idea moving from trying to have an object go down the ramp to making it make the corner to making several objects go down the ramp.

In sum, through the face-to-face PLC meetings, the teachers had the opportunity to engage in the problem-solving process by talking about their challenges in teaching science to young children. In addition, they generated alternative strategies to solve those problems. The teachers also evaluated their science teaching and children's science learning during the meetings. The field notes by the facilitator, "*A lot of in-depth conversations. Teachers talked about their challenges and solutions to those. Teachers evaluated their own practices*" also supported the theme, *Inquiry about Science Teaching*.

Theme 3: Reflection. During the face-to-face PLC sessions, the teachers revisited the Ramps and Pathways workshop and the ramps materials and activities in their own classroom. They also reflected on their own teaching practices and children's work and learning during the sessions. When Cloy was developing a lesson plan with other teachers, she revisited the Ramps and Pathways workshop about how the presenter set up the ramps activities saying, "*I loved the presentation, how she started on the table... I liked how she had one that was already set up like a ramp and another one and then another one just flat on the table…*" The way that the workshop leader had set up the materials in various ways seemed to have prompted Cloy to think about different ways to stimulate and facilitate children's thinking, which is consistent with constructivist approach to facilitating children's learning (Brewer & Daane, 2002). This revisiting helped Cloy develop her goals. She developed a three-tiered discovery (e.g., doing basic, adding sand, and adding water) to introduce ramps and pathways to children and encourage children to use multiple senses to explore with a variety of materials and to explore different kinds of problems provided by different types of materials and objects.

When Emily was the discussion leader in session three, she revisited how the Ramps and Pathways activities were implemented in her classroom and how the child interacted with the ramps materials:

> "*... Um so we had a student teacher set this up in the block area away to get them to start using it and in a different way. With this big boat and these [blocks] as slides and these blocks have pictures of teachers and children on them. And so Haley started using it and she took this little blue wood guy and was just dropping down the slide? (laugh)*"

The quote illustrates that the teacher, Emily, was thinking and discussing the Ramps and Pathways activities again (e.g., how the teacher set up the activities, what the child was doing with materials available in the block area). She revisited how the activities were set up in the classroom and how children explored the materials in ways that teachers did not anticipate.

When the teachers were discussing how to engage children in science activities using 5E instruction in session five (see Figure 4.7), Cloy reflected on her own practice:

> "*Um I put out materials, change of the materials that are there. Ask them questions about why they're doing things and I don't know I might be going too far. Too far ahead.*"

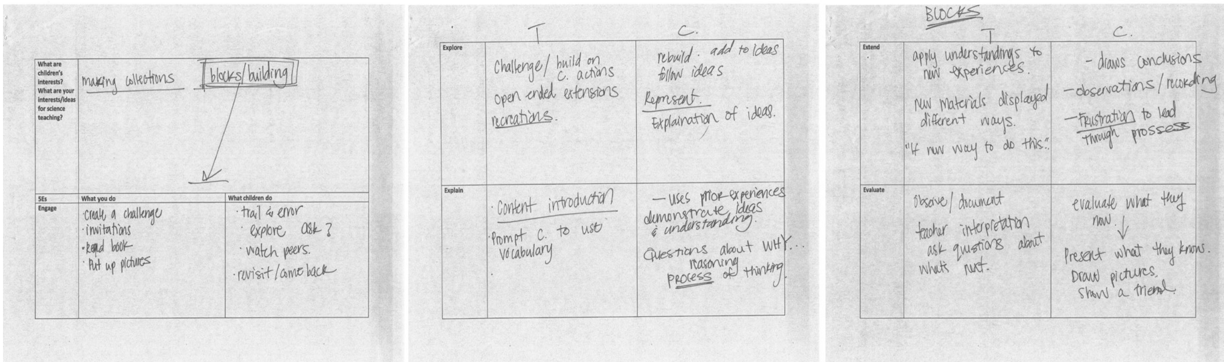


Figure 4.7. 5E Instruction Developed by Teachers

When the teachers were talking about how the Ramps and Pathways activities were implemented in their classrooms, they also reflected on children's work and learning. When Cloy was the discussion leader in session five, she shared how children explored and interacted with the ramps materials. She specifically focused on the learning of a child, Tom, and described Tom's exploration of the materials and the activity:

> "*Tom was very funny. He did a couple of things on the table… and then putting on the floor… and then he made this giant thing… and then that's him pushing. So he pushed the marble (laugh), push the marble, push the marble, what, probably 20 minutes. Push the marble back and forth… and then finally when got a little triangle so he had little ramp to get started. It was very funny. I mean like he did it for half of the free play time… and then finally got that and let it go and then he was like all done okay oh okay*"

This quote illustrates the child's inquiry problem-solving processes through active, self-directed experimentation. The teacher was reflecting on Tom's active and persistent interactions with the ramps and pathways materials to solve the problem of having a marble go down the ramp after multiple unsuccessful attempts.

In sum, during the face-to-face PLC meetings, the teachers had the opportunity to revisit the Ramps and Pathways workshop and how the Ramps and Pathways activities worked in their classrooms. They also reflected on children's science learning and their own science teaching practices. The field notes by the facilitator, "*When the discussion leader shared her practices, lots of revisit and reflections happened*" also provided evidence to support the theme, *Reflection*.

Theme 4: Positive Climate. Throughout the face-to-face PLC sessions, the teachers expressed many positive emotions and excitement. While the teachers shared their ideas and practices and worked collaboratively, they laughed together many times. Teachers also expressed feelings of excitement when they were planning a lesson with the ramps materials saying, "*I think I am excited (laugh)*," and "*I'm really interested to see*." Emily expressed her interest at the beginning of the sessions saying, "*I'm just interested to see how everyone else put materials in classroom maybe new materials you tried or um just creative ways that other people think about presenting them in their rooms*." In sum, during the face-to-face PLC sessions, the teachers created positive climate through expressing positive emotions and showing excitement about sharing new ideas and creative ways in teaching science. The field notes by the facilitator, "*lots of laughs, teachers seemed to really enjoy the sessions*" supported the theme, *Positive Climate*.

Emerging Themes from Online PLC Sessions

In order to gain a better understanding about the online context of teachers who participated in the online PLC sessions, the teachers completed an online survey asking questions about their participation information after each session ended. Table 4.2 shows the teachers' log-in information during the online PLC sessions.

Table 4.2

Teachers' Log-in Information during the Online PLC Sessions (n = 2)

	Session	Log-in Date	Log-in Place	Work Done	Log-in Duration
Kate	1	Wednesday	Home	Read postings; Replied postings	< 0.5 hour
	2	Wednesday	Home	Read postings; Replied postings	< 0.5 hour
	3	Thursday	Home	Uploaded the files; Read postings; Uploaded postings	< 0.5 hour
	4	Wednesday	Home	Read postings	< 0.5 hour
	5	Wednesday	Home	Read postings	< 0.5 hour
	6	Wednesday	Home	Read postings	< 0.5 hour
Kelly	1	Wednesday	Center	Read postings; Replied postings	0.5 – 1 hour
	2	Wednesday	Home	Read postings; Printed out the reading to read	0.5 – 1 hour
	3	Tuesday	Center	Read postings	0.5 – 1 hour
	4	Tuesday	Center	Uploaded the files; Read postings; Uploaded postings	1 – 1.5 hour
	5	Tuesday	Center	Read postings	1 – 1.5 hour
	6	Wednesday	Center; Home	Read postings	1 – 1.5 hour
Lilly	Unknown				
Betty	Unknown				

Kate answered that she participated in the online PLC sessions at home on Wednesdays or Thursdays and spent less than 0.5 hour in each session. She also reported that she read and replied postings and uploaded the files and postings during the online PLC sessions. An approximate total of time spent online for Kate was 3 hours. Kelly reported that she participated in the online PLC sessions either at home or at center on

Tuesdays or Wednesdays. She answered that she spent between 0.5 – 1.5 hours in each session. She reported that she read and replied postings, uploaded the files and postings, and printed out the reading during the online PLC sessions. An approximate total of time spent online for Kelly was 7.5 hours. The other two teachers, Lilly and Betty did not complete any surveys about their online participation.

For research question 2, online archives (i.e., postings) during the online PLC sessions were collected and qualitatively analyzed for emerging themes. Three main themes and 7 subthemes emanated from the iterative analyses of the online sessions. The themes included (1) revisiting the Ramps and Pathways activities, child learning, and teacher practice; (2) sharing ideas, thoughts, and documentation; and (3) creating positive climate (see Table 4.3 for detailed information). However, one caveat is that these themes were based on a fairly limited number of data points (i.e., 13 pages of text and 34 codes in total compared to 185 pages of text and 2,382 codes from face-to-face PLC sessions) due to the low participation of online group teachers.

Table 4.3

Definition and Examples of the Themes and Subthemes during the Online PLC

Theme	**Subthemes**	**Definition**	**Examples/ Quotes**
1. Revisit	1a. Revisiting the Ramps and Pathways activities	The action of thinking, examining, or discussing how the Ramps activities worked in the classroom again	*"First day with Ramps. Nothing was said about what they were or what to do with them*."
	1b. Revisiting child work and learning	The action of thinking, examining, or discussing child work and learning during the Ramps activities again	"*He was experimenting with a grey wheel from the Legos*."
	1c. Revisiting teacher own practice	The action of thinking, examining, or discussing	*"I had the children keep them in the block area*

		teacher own practice during the Ramps activities again	*today…*"
2. Share	2a. Sharing thoughts and ideas about the Ramps and Pathways activities	The action of sharing thoughts or ideas about the Ramps and Pathways activities	*"… The ramps are a high interest area in the classroom that gives the children immediate results as they try out their ideas for constructing and controlling the marbles direction on the ramps*."
	2b. Sharing documentation about the Ramps and Pathways activities	The action of sharing documentation about the Ramps and Pathways activities	*e.g., Pictures; videos*
3. Positive Climate	3a. Using positive emoticons	An emotional response that is pleasant	e.g., *like- or love-emoticons*
	3b. Expressing interests	An emotional response that includes curiosity and interest	"*I am curious to see what other teachers let their children do with the ramps and what other materials are used along with them*."

Theme 1: Revisit. During the online PLC sessions, the teachers revisited the Ramps activities, children's learning, and their teaching practice. When Kelly was the discussion leader, she revisited how she introduced the Ramps and Pathways activities and how children interacted with the ramps materials in her classroom by posting, "*First day with the ramps! All I did was put them out but didn't say what there were or how to use them. This little boy made a track for his car*." (see Figure 4.8).

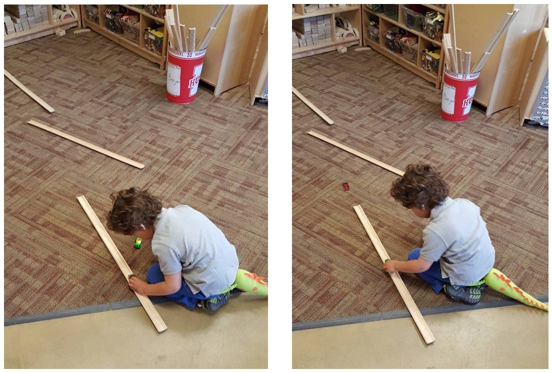


Figure 4.8. Pictures of First Day with the Ramps Materials by Kelly

Kelly also revisited a child's work by saying, "*He was experimenting with a grey wheel from the Legos*," (see Figure 4.9) and her own teaching by saying, "*I had the children keep them in the block area today but as you see they got creative by bringing in chairs and not using any sort of building blocks for them yet*." (see Figure 4.10). Figure 4.10 shows how the children explored the ramps materials in creative ways using various other materials and furniture as well as building blocks and ramps in their classroom.

Figure 4.9. Pictures of a Child Experimenting with a Grey Wheel by Kelly

Figure 4.10. Pictures of Children Being Creative with the Ramps Materials by Kelly

The artifacts shared by the teacher included photos of children using the ramps and pathways materials alone or with a few other children; however, teachers' reflections were limited to what children did with the materials rather than how children extended the activity or how the teacher used the opportunity for teaching. The notes by the facilitator, "*The discussion leader revisited the Ramps activities and child learning*" also support the theme, *Revisit*.

Theme 2: Share. During the online PLC sessions, the teachers shared their thoughts, ideas, and documentation (e.g., pictures, videos) related to the Ramps and Pathways activities on the Facebook page. When the articles related to the Ramps and Pathways activities were provided during session two, Kate shared her thoughts about an article and said that the ramps and block area might be a valuable context where children could possibly learn to try out their ideas multiple times and solve problems:

"*In the first article I was very interested in the 4 y/o male, Brice, being the Coolest Builder! I love that he spent 46 minutes constructing ramps. Even though he had to rebuild 12+ times due to his ramp system collapsing or being knocked down by another student, he continued to build. The ramps are a high interest area in the classroom that gives the children immediate results as they try out their ideas for constructing and controlling the marbles direction on the ramps*."

When Kelly was the discussion leader in session four, she shared what she observed and documented (i.e., pictures and videos of children's using ramps and blocks; see Figure 4.11) and also briefly shared her plan to take materials to a different context (i.e., outside) with additional materials (i.e., tennis balls). She explained the pictures of children and the ramps constructions by posting, "*Not what I expected to happen. It took a lot not to go over and show them how to build and make cool ramps with them. Tomorrow we will be taking them outside and seeing what we can do with ramps and tennis balls!!*"

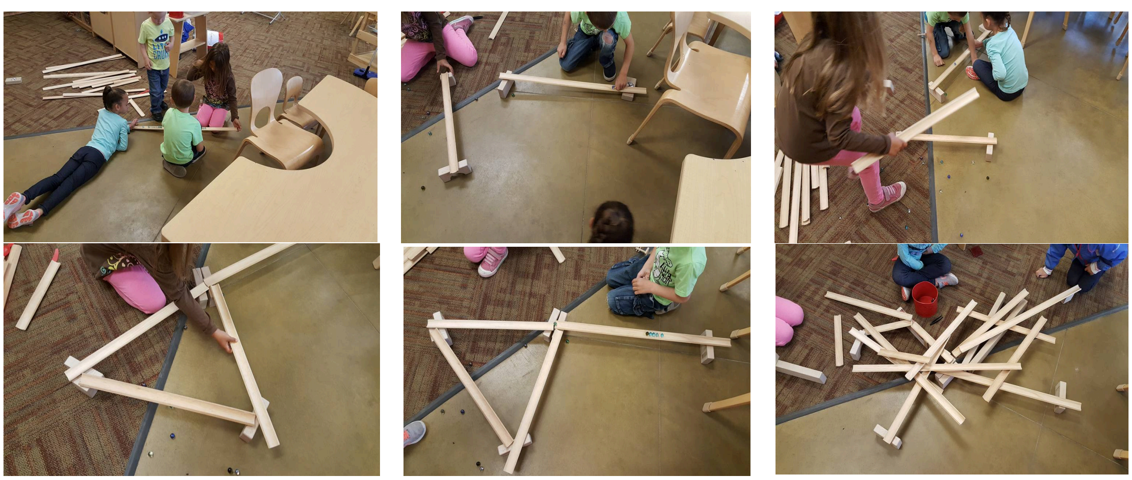


Figure 4.11. Pictures Documented by Kelly

Kate also shared what a similar collection of photos and videos when she was leading the group in session three (see Figure 4.12). She did not explain the videos and pictures she documented, but she shared that one of the problems children tried to solve was to make the marble roll up. No further discussion was provided, however.

Figure 4.12. Pictures Documented by Kate

The facilitator's note supported the theme, Share, "*documentation pictures and videos were shared*". However, the teachers in the online PLC sessions seemed to share less according to the notes by the facilitator, "*less sharing*".

Theme 3: Positive Climate. When the online PLC sessions started, the teachers expressed positive emotions through the like- and love-emoticon buttons on Facebook page. The teachers were interested in participating in the online PLC sessions. Kate expressed her excitement by posting, "*I look forward to working with you and my online group. I am very excited to teach my students all that I have learned!"* Kelly also expressed her interest by posting, "*I am curious to see what other teachers let their children do with the ramps and what other materials are used along with them*." The online PLC group teachers were excited about participating in the sessions and sharing teaching ideas and practices with other teachers. The notes by the facilitator, "*lots of like emoticons*" also support the theme, *Positive Climate*.

Similarities and Differences between Face-to-face and Online PLC Sessions

Emerging themes from face-to-face PLC sessions were compared to those from online PLC sessions in order to explore how they were similar and different. The amount of data was also examined to understand the depth and flow of the face-to-face and online sessions. In this study, 2,382 codes were emerged from the face-to-face sessions, and 34 codes were emerged from the online sessions. Both face-to-face and online group teachers shared science teaching practices and ideas during the PLC sessions. In addition, both groups of teachers shared their documentation about how the Ramps and Pathways activities worked in their classrooms by showing pictures and videos. However, the face-to-face PLC group shared their thoughts, practices, and documentation more actively than the online PLC group. More specifically, during the face-to-face PLC sessions, there were a large number of back-and-forth conversations about their teaching practices from presentation of the materials to reflection of their teaching and children's responses. In addition, the face-to-face PLC group teachers were more supportive of each other than their online counterparts. The face-to-face group teachers commented on one another's ideas, suggested new strategies or solutions to a problem posed by one another, and worked collaboratively to develop lesson plans. More support and collaboration happened during the face-to-face PLC sessions. On the other hand, the online group teachers were quiet and provided little feedback to other teachers. In addition, collaboration among teachers seemed more challenging in the online PLC context.

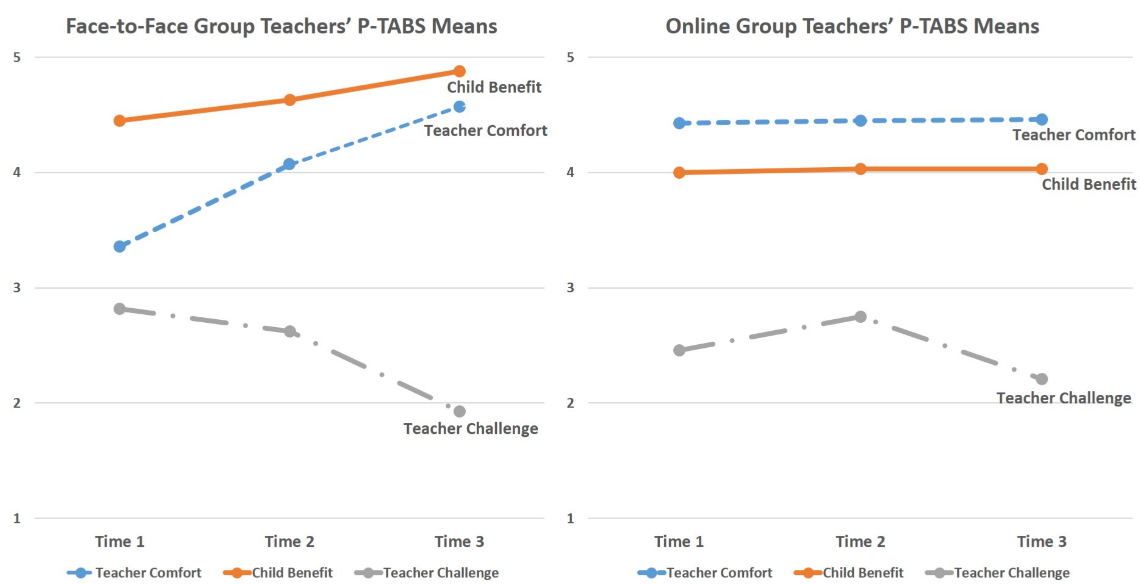
Both face-to-face and online group teachers inquired about their science teaching and children's learning during the PLC sessions, but significantly less discussion was observed and coded during the online PLC than during face-to-face PLC. The face-to-face PLC group teachers spent more time problem-solving, inquiring, and evaluating child learning and science teaching. The face-to-face group teachers also engaged in finding solutions to the challenges they identified. On the other hand, the online PLC group teachers were less engaged in problem-solving, inquiring and evaluating children's learning and their science teaching practices. More in-depth discussion and inquiry about science teaching and learning happened during the face-to-face PLC sessions than the online PLC sessions.

While participating in the PLC sessions, both face-to-face and online group teachers implemented the Ramps and Pathways activities in their classrooms and revisited the Ramps and Pathways activities. However, only face-to-face PLC group teachers reflected in-depth on the Ramps and Pathways activities by focusing on child learning and their teaching practices. They expressed their opinions, ideas, and beliefs on science teaching and child learning freely and deeply.

A positive climate was created through both face-to-face and online PLC sessions. However, the positive climate seemed to be sustained during the face-to-face PLC sessions only. The online PLC group teachers showed interest and positive emotions at the beginning of the sessions, but it seems to have faded away as PLC sessions continued. In online PLC session three, one teacher expressed her challenge of being too busy with other things by saying, "*I'm so sorry to do this but I have had some crazy things happen the last 3 weeks (death in the family, personal illness, new/additional job responsibilities)* *and I just don't have time to read all of the training links and do all the FB posts required in this training. I'm so sorry!*" She expressed challenges and discomfort of not having time to participate in the online PLC sessions. The notes by the facilitator, "*no like- and love-emoticon buttons from session three*," "*quiet*," and "*not engaged*" also support that online group teachers' positive emotions and interest did not last throughout the duration of the sessions. On the other hand, a positive climate seemed to be maintained throughout the face-to-face PLC sessions. The face-to-face PLC group teachers shared positive emotions with other teachers throughout the sessions. A great deal of positive emotions were observed and recoded while supporting the learning and working collaboratively. In sum, each group created and developed their PLC in different ways. The face-to-face group created more opportunities to work together and solve problems together while meeting as a team, whereas the online group used the online space to present their reflections about activities rather than planning activities and follow them up together. However, there were also similarities between two groups in that both groups shared their ideas, practices, and documentation and revisited science activities, child learning, and their teaching practices during the PLC sessions, which were considered as the components of effective PLCs.

Change in Face-to-face Group Teachers' Attitudes and Beliefs

For research question 3, quantitative data were collected through the P-TABS survey (see Appendix B). Figure 4.13. (graph on the left) shows the changes in the face-to-face group teachers' attitudes and beliefs toward science teaching. One of the participants was not able to attend the workshop due to a family emergency so I did not include her P-TABS score at Time 2 in the analysis. The face-to-face group teachers' comfort with planning and implementing different science activities and perception about how science improves young children's science and other learning tended to increase after the workshop and after the PLC sessions. In addition, the face-to-face group teachers' challenges with their lack of science knowledge, science teaching ability, and preparation time tended to decrease after the workshop and after the PLC sessions. Although a statistical analysis is not meaningful to conduct due to the small number of participants, a series of paired-samples t-tests revealed that face-to-face group teachers' comfort with planning and implementing various science activities in the classroom increased significantly after the workshop ($t(2) = -10.58$, $p = .009$, $d = 1.74$) and after the face-to-face PLC ($t(3) = -6.07$, $p = .009$, $d = 4.28$) (see Appendix G).



Note. Time 1 refers to the time before the workshop. Time 2 refers to the time after the workshop and before the PLC sessions. Time 3 refers to the time after the PLC sessions. Possible range is 1 through 5.

Figure 4.13. Changes in Teachers' P-TABS Means by PLC Groups (N = 8)

Change in Online Group Teachers' Attitudes and Beliefs

For research question 4, quantitative data were collected through the P-TABS survey (see Appendix B). Figure 4.13. (graph on the right) shows the changes in the online group teachers' attitudes and beliefs toward science teaching. The online group teachers' comfort with planning and implementing different science activities and perception about how science improves young children's science and other learning tended to remain the same after the workshop and after the PLC sessions. On the other hand, the online group teachers' challenges with their lack of science knowledge, science teaching ability, and preparation time tended to increase after the workshop and decrease after the PLC sessions. Paired-samples t-tests revealed that online group teachers' comfort with planning and doing different science activities did not increase significantly after the workshop, after the online PLC, or after the combination of workshop and online PLC. In addition, online group teachers' beliefs about children's science learning benefits did not change significantly after the workshop, after the online PLC, or after the combination of workshop and online PLC (see Appendix H).

Teachers' Perceptions of Face-to-face PLC Sessions

For research question 5, qualitative data were collected through the open-ended survey (see Appendix D). Five themes and 15 subthemes emanated from the open-ended survey responses of face-to-face group teachers (see Table 4.4). The themes from the face-to-face PLC teachers included the teachers' change, the teachers' benefits, the teachers' challenges, and their suggestions and appreciation for the PLC sessions.

Table 4.4

Themes and Subthemes from Face-to-face PLC Sessions (n = 4)

Themes	**Subthemes**
1. Teacher Changes	1a. More reflections
	1b. More resources
	1c. More comfort and confidence
	1d. More knowledge and ideas

2. Teacher Benefits	2a. Resources and information 2b. Reflections 2c. Different experience 2d. Set time
3. Teacher Challenges	3a. Less experience and education 3b. Finding time to implement the activities
4. Suggestions	4a. Online discussion 4b. More time on articles and research
5. Appreciation	5a. Opportunities, resources, experiences 5b. Atmosphere of respect 5c. Openness

Theme 1: teacher changes. The teachers reported how they have changed after participating in the face-to-face PLC sessions. The teachers reported that they had more time to reflect on their own science teaching. One participant shared, "*I have reflected more on my role as a teacher – focusing more with these materials on play/exploration and how my role of modeling and self talk*." The teachers also expressed that more resources were available for science teaching saying, "*I feel I have more resources to help me if needed*." In addition, the teachers reported more comfort and more confidence with teaching science. One participant expressed, "*This group has made me more comfortable with trying more science related activities in the classroom.*" The teachers also shared that they gained more knowledge and ideas for science teaching through the PLC sessions. One teacher reported, "*Brought ideas/lessons back to my school that I would not have otherwise*."

Theme 2: teacher benefits. The teachers shared what the benefits were from participating in the face-to-face PLC sessions. The teachers reported that the resources and information provided during the PLC sessions were beneficial to their science teaching. One teacher shared, "*The resources provided – articles, theory, practice lesson plans really grounded our implementations*." The teachers also shared that the group reflections were beneficial to them. One teacher reported, "*The group reflections allowed me to see materials – lessons from everyone's view point/perspective*." In addition, the teachers reported that they liked the different classroom experiences. One teacher shared, "*The different classroom experiences shared by participants was good to see*." The teachers also reported that they liked the time to talk with other teachers. One teacher expressed, "*It was good to have dedicated time to discussing my work with other professionals. It helped me look at my classroom through a different lens and evaluate my own teaching*."

Theme 3: teacher challenges. Teachers reported what the challenges were from participating in the face-to-face PLC sessions. One teacher shared, "*I have much less experience and education in early childhood, but this gave me an incredible change to gain information and insight from some very well educated/informed teachers*!!" Another teacher reported that it was challenging for her to find the time to do the science activities in a meaningful way saying, "*Just being sure that I could find the time to implement the activities in a meaningful way in the classroom*."

Theme 4: suggestions. Participants suggested how the face-to-face PLC session could be improved. One teacher suggested, "*If time allowed – a discussion board online – for in between sessions and after training/PLC service ends*" Another teacher expressed, "*I think it would be good to reflect more on articles and research and connect them to our teaching strategies in the classroom.*"

Theme 5: appreciation. The teachers appreciated the opportunities, the atmosphere of respect, and the openness during the face-to-face PLC sessions. One teacher shared, "*I really appreciate the opportunity to be reflective about this topic*." Another teacher expressed, "*You did a nice job of providing resources for us and creating an atmosphere of respect and openness that allowed us to share openly*."

Teachers' Perceptions of Online PLC Sessions

For research question 6, qualitative data were collected through the open-ended survey (see Appendix D). Three themes and 7 subthemes emanated from the open-ended survey responses of online group teachers (see Table 4.5). The themes from the online PLC teachers included the teachers' change, the teachers' benefits, and the teachers' challenges.

Table 4.5

Themes and Subthemes from Online PLC Sessions (n = 2)

Themes	**Subthemes**
1. Teacher Changes	1a. Closer observation and documentation
	1b. More excitement on science teaching
2. Teacher Benefits	2a. Convenience
	2b. Ideas from other teachers
	2d. Helpful articles
3. Teacher Challenges	3a. Too busy with other things
	3b. Time

Theme 1: teacher changes. The teachers reported how they have changed after participating in the online PLC sessions. The teachers reported they watched closer and documented the children's science activity. One participant shared, "*I watched the*

children's use of the ramps and pathways closer and documented to post the pics and videos. I am more excited to teach stem skills with Ramps and pathways."

Theme 2: teacher benefits. The teachers shared what the benefits were from participating in the online PLC sessions. The teachers reported that it was convenient to participate on their own time at home and they were able to get different ideas and helpful articles. One participant shared, "*It would have been very convenient to observe in my classroom and then post on my own time at home.*" Another teacher reported, "*You get ideas from other teachers and you also get to read some helpful articles*."

Theme 3: teacher challenges. The teachers reported what the challenges were from participating in the online PLC sessions. One teacher shared, "*Soon after the PLC sessions started, my friend passed away suddenly and I'm now helping to care for his wife. Also, I went to Seattle to see my oldest son for a week and was busy preparing for that trip. Then I found out that I was doing the school age program and needed to plan 3 months of field trips and new curriculum. Then my youngest son graduated from high school. So being too busy was my biggest challenge.*" Another teacher shared, "*It was challenging to read and comment on every post*."

CHAPTER 5

DISCUSSION

The purpose of this qualitative case study was to explore the content, processes, and dynamics of face-to-face and online professional learning communities (PLCs) where preschool teachers worked together to build their competence in science teaching and learning. Another purpose of this study was to investigate the changes in the preschool teachers' attitudes and beliefs toward science teaching after they participated in one of the two different forms of PLCs (i.e., face-to-face or online) following a workshop focused on physical science concepts and processes.

Although it is critical to learn the key components of PLCs that make early childhood science teaching and learning more effective and sustainable, little empirical research looked into the effectiveness, dynamics and processes of early childhood PLCs focusing on science education. The findings from this study provide an insight and a detailed description of face-to-face and online PLC sessions as well as their key components observed in the process. In addition, the findings from this study provide early childhood researchers, trainers, and teachers with teachers' perceived benefits and challenges of PLCs as aligned with their actual behaviors and conversations occurring during PLC sessions, which can serve as a basis for further research that connects the PLC components and changes in practice.

Emerging Themes from Face-to-face and Online PLC Sessions

Throughout the face-to-face and online PLC sessions, a variety of themes were found. Specifically, during the face-to-face PLC sessions, teachers worked collaboratively, inquired about science teaching and child learning, reflected on teaching practices, and created positive climate for learning. During the online PLC sessions, teachers revisited their teaching practices, shared their ideas and practices, and created positive climate.

The teachers in the two groups discussed similar content but formed their PLC in a different way. In general, teachers in the face-to-face PLC group shared their ideas, thoughts, and practices more actively by engaging in a larger number of back-and-forth conversations than teachers in the online PLC group. The face-to-face group teachers shared how the ramps and pathways activities worked in their classrooms and how they used or would use the ideas in their science teaching. At the end of the PLC sessions, the face-to-face group teachers expressed that they enjoyed various classroom experiences shared by other teachers. The face-to-face group teachers also supported one another during PLC sessions as resources by commenting on ideas presented and suggesting solutions or new ideas to a problem posed by other teachers. The face-to-face group also collaborated toward effective science teaching by developing science lesson plans together. In effective PLCs, teachers tended to be encouraged to reflect on their teaching practices as well as on children's learning, collaborate with other teachers to improve child learning by engaging in continuous collective learning, and inquire about classroom issues or problems by embedding the practices in their own classroom settings and aiming at improving child learning (Darling-Hammond & Richardson, 2009; Fulton & Britton, 2011; Hord, 1997; Mundry & Stiles, 2009; Nelson et al., 2010; Stoll et al., 2006; Worth, 2010). The themes that emerged from face-to-face PLC sessions were consistent with the characteristics of successful professional development observed in previous research in that teachers shared their knowledge, skills, and practices, supported each other by providing constructive feedback, and created science lesson plans collaboratively (Hong et al., 2013; Sheridan et al., 2009; Vescio et al., 2008; Wesley & Buysse, 2006).

The teachers in the face-to-face PLC group in this study engaged in the problem-solving process by defining challenges/problems in implementing ramps and pathways activities and explaining science concepts to young children and by finding alternatives or solutions to those challenges. The teachers in the face-to-face group also inquired about science teaching (e.g., how to effectively talk about science with young children) and had continuous reflective discussions about their science teaching as well as children's science learning. After participating in PLC sessions, the teachers in the face-to-face group reported that they reflected more on their role as a teacher and that group reflections helped them see materials and lessons from other teachers' viewpoint.

The findings from this study are also supportive of Cunningham and her colleagues (2015) where they found significant changes in teachers' knowledge and practices after providing support for teachers' development. The face-to-face group teachers reported that they gained more knowledge, ideas, resources, and lessons to help them with science teaching after participating in the PLC sessions. The findings from this study and Cunningham et al. (2015) provide support for the use of relationship-based and socially created PD as a means to improve teachers' knowledge, skills, and practices.

The online PLC group teachers in this study also discussed how they implemented the ramps and pathways activities in their classrooms. The online group teachers revisited how they introduced the ramps and pathways activities and how children interacted with the ramps materials. They also shared their documentation about the ramps and pathways activities and added thoughts to the documentation on the shared space. After participating in PLC sessions, the online group teachers reported that it was beneficial for them to get ideas from other teachers. They also reported that they observed and documented their children's use of the ramps materials more closely to post the pictures and videos on the Facebook page. However, online group teachers' reflections tended to be limited to what children did with the ramps materials rather than how the teacher used the moment meaningfully for effective teaching. They tended to post the pictures and videos of children with the ramps materials without further discussions or reflections. In addition, the online group teachers tended to provide little feedback to other teachers during the PLC sessions, which may indicate that it was more challenging for the online group to work collaboratively in developing science lessons together and sharing their observations during the implementation of those activities.

Previous studies indicated that online learning communities foster a learning culture and collaboration among participants and provide maximum flexibility in that information is available at any time through online (Little & King, 2007; Lock, 2006; Lowes et al., 2007; Pringle et al., 2010). The key factors that make online learning effective are found to include collaboration, voluntary participation, empowerment, and contributions from all members (Hou, 2015; Palloff & Pratt, 2007). However, these factors were not observed in the online PLC group in the current study. It is possible that the online group teachers may have struggled to establish collaborative relationships remotely with other teachers and thus had a hard time sharing their ideas and practices and engaging in self-reflection in an online setting. In addition, it is possible that the facilitator (i.e., primary investigator) did not have enough knowledge or information about the operation and facilitation of online PLC sessions because there was little research about online PLCs in early childhood science education. Therefore, it is fairly reasonable to assume that the facilitator may not have provided appropriate support or guidance that could promote active discussions, collaboration, and reflection among the online group teachers. The facilitator in this study was expected to provide the same level of content support and facilitation to both groups of teachers, but it turned out that the facilitator might have had to use a different set of strategies to facilitate the online PLC group.

Although the teachers in the online PLC group did not participate very actively in online discussions and reflections, a positive climate for learning was created at the beginning. The online group teachers showed interest and positive emotions, but it has faded away as the online sessions continued. These findings are consistent with negative aspects of online communication in the literature. Communicating online has the risk of isolating participants, so online participants are likely to be silent and disappear more easily from the online community (Palloff & Pratt, 2007). It is possible that the online PLC group teachers in this study felt isolated so they did not participate actively, share openly, and engage collaboratively in dialogue, which reduced opportunities for them to engage in collaboration and build collegiality. It is also possible that the group dynamics was different due to the size of the group. In this study, only two teachers engaged in the online PLC sessions consistently while the other two stayed unengaged during the online sessions. Therefore, it is likely that there were not an optimal number of members in the online PLC sessions, which may have limited the development of substantive conversations among the teachers (Graham, 2007).

Online learning can be challenging when it does not include direct human contact or face-to-face conversations. The online PLC, in the current study, was implemented only via asynchronous discussions and interactions to help teachers have more flexibility in participating in the PLC sessions. However, a certain level of synchronous interactions via videoconferencing and cyber mentoring may have facilitated more active interactions among teachers as suggested by Johnson et al. (2006) and Pringle et al. (2010).

In sum, the findings from this study showed that teachers tended to have more in-depth conversations, build more supportive and collaborative relationships, share ideas and reflections more meaningfully, and create more positive climate during the face-to-face PLC sessions than during online PLC sessions. However, the findings need to be interpreted cautiously in that there are many potential factors (e.g., human and social factors such as relationships among teachers, group dynamics, individual teacher characteristics such as educational backgrounds, individual teacher's openness to change, levels of collegiality and collaboration, etc.) (Guo et al., 2011; MaGinty et al., 2008; Sheridan et al., 2009; Stoll et al., 2006) that may have resulted in differences in group dynamics between the face-to-face and online PLC sessions.

Change in Face-to-face and Online PLC Group Teachers' Attitudes and Beliefs

The findings provide insights as to the changes in teachers' attitudes and beliefs toward science teaching after the face-to-face PLC or the online PLC. The face-to-face group teachers reported that they were more comfortable with planning and implementing different science activities and perceived more positively about how science improved young children's science and other learning after the workshop and after the PLC sessions. Consistent with these findings, the face-to-face group teachers reported that they are more comfortable and confident with implementing science activities with children in their classrooms in the open-ended post-PLC survey. Furthermore, the face-to-face group teachers reported that their challenges to preparation time, science teaching ability, and lack of science knowledge decreased after the workshop and after the PLC sessions. These findings are consistent with previous studies about positive effects of specialized training and professional learning communities on teachers' competence and confidence (Fukkink & Lont, 2007; Weiser, 2012).

On the other hand, the online group teachers in this study did not show any changes in their beliefs and attitudes toward science teaching after they participated in the workshop and the online PLC sessions. Previous studies suggested that the changes in teacher' attitude toward teaching happened when they had higher levels of teachers' collegiality and collaboration (Guo et al., 2011; McGinty et al., 2008). Therefore, it is possible to assume that, in this study, the online group teachers had lower levels of collegiality and collaboration due to the low engagement and fewer interactions compared to the face-to-face group teachers, which might have led to little change in their attitudes toward science teaching. According to the facilitator notes, the online group teachers provided less constructive feedback to other teachers, had less collaborative work together, and engaged in less reflective discussions with other teachers. The quality of PLC (e.g., a level of collegiality and collaboration) was not measured in this study, but future studies should consider including this variable because the quality of PLC can impact teacher practices and child learning. The quality of PLC can be different depending on many other factors (e.g., PLC formats, teacher characteristics, center environment, level of collegiality, participation length, etc.) (Guo et al., 2011; Hord, 2009; Louis et al., 1996; McGinty et al., 2008; Stoll et al., 2006). Hord (2009) indicated that PLCs can be successful when workplace climate supports collaborative and reflective dialogue among teachers and provides space and time for teachers' meetings and learning. McGinty et al. (2008) found that teachers' perceived high collegiality (e.g., supporting, sharing, helping, collaborating) was related to their positive attitudes toward teaching. Similarly, Guo et al. (2011) suggested that higher levels of teacher collegiality and collaboration (e.g., supportive relationships and shared education goals) with higher quality instruction were related to greater child learning.

Another possibility can be that asynchronous environments might have limited collaboration and collegiality of the online PLC. The online group teachers had sufficient time to think and respond to the discussion topics or other teachers' postings because no instant response was required. The teachers shared the benefit from participating in the online PLC session. One of the online group teachers reported that it has been very convenient to observe in her classroom and then post on her own time at home, which is consistent with the benefits of online learning environments (e.g., flexibility and convenience) (Little & King, 2007). However, the lack of instant social interactions in such asynchronous environments may have resulted in a series of one-way discussions due to their failure to build relationships and sustain their interactions with other participants (Branon & Essex, 2001; Hou & Wu, 2011). The online group teachers in this study were separated by place and time. There was no scheduled time for them to have virtual meetings while they had unlimited time to participate in the PLC sessions online at any time. On the other hand, there is a possibility that the set meeting time for the face-to-face group teachers seemed to have played a positive role as an external motivator because it helped and motivated them block time and be physically present to discuss their teaching practices and child learning. Therefore, it is possible that such synchronous environments (e.g., real-time) may have encouraged instant feedback and instant sharing information and resulted in active participation and back-and-forth discussions during the face-to-face PLC sessions (Hou & Wu, 2011). After participating in the PLC sessions, one of the face-to-face group teachers expressed an appreciation for a set time for meetings because it allowed her to sit down and reflect on her teaching practices and children's learning with other teachers:

> "*I think the biggest thing that I'm thankful for is the time. Because you don't always have a lot of time to sit down and talk with each other, to talk about these concepts and this was time that we blocked out. You didn't have to worry about other things that were going on. Um… because working in toddler rooms and preschool rooms, it's very busy and so to sit down actually reflect with other group of other teachers was really valuable*."

Limitations and Implications for Future Research

This study has several limitations. The first limitation of this qualitative study is that the researcher brought her own perspective to the interpretation. Therefore, there is a limitation to be applicable and generalizable to other studies due to the personal interpretation. Another limitation to this study is that the facilitator in this study did not have sufficient knowledge and understanding about how to effectively motivate and engage online group teachers and how to facilitate the online interactions among teachers.

This was partly due to a lack of research-based information available regarding asynchronous online PLCs in early childhood professional development. Additional research is needed to specifically explore the effective strategies to engage early childhood teachers in online PLCs. Third, quantitative data collected in this study showed the changes in the face-to-face and online PLC group teachers' attitudes and beliefs toward science teaching. However, this study provided little information about changes in teachers' knowledge, skills, and practices in science teaching and changes in children's learning as they were not directly assessed by observations or assessments. Future research should consider including classroom observations. Finally, in this study, the teachers in the online PLC group did not have sufficient time to build relationships except for the time when they had participated in the Ramps and Pathways workshop. Supportive and collaborative relationships among participants are critical for effective PLCs (Cunningham et al., 2015). Therefore, future study should consider providing initial face-to-face or synchronous meeting times for teachers before the asynchronous PLC sessions, which can create opportunities for them to get to know one another and build positive relationships for learning.

This study is meaningful in that it examined the dynamics and effectiveness of face-to-face and online PLCs focusing on science content. However, there is much information that remains unclear and needs to be further explored: What are the key components of PLC that make a difference in early childhood teachers' attitudes toward science teaching? What are the key components of PLC that help teachers feel empowered to teach science in their classroom? What is the mechanism through which these PD efforts become sustainable? Future studies should also examine the long-term impacts of PLCs on science teaching and learning by collecting data on how teachers apply the information they gained from the workshop and the PLC sessions and how PLCs improve children's science learning and cognitive development through teachers' knowledge, attitudes, and practices.

Teacher characteristics and qualifications are important factors that may significantly contribute to the quality of PD experiences (Louis et al., 1996; Stoll et al., 2006). The participants of this study were all from NAEYC-accredited, center-based early childhood programs. However, further studies are needed to explore the PLCs and their influence on teachers at different types of settings (e.g., family child care homes, non-NAEYC accredited child care centers, child care centers in rural area communities, etc.). In addition, future research is needed to explore the level of quality in PLCs in different forms (i.e., face-to-face, online, and hybrid) and their influence on teacher practices and child learning. Such future research will provide information about innovative ways to build the PLCs for more effective science teaching and learning in early childhood settings. Furthermore, in this study, there were low levels of commitment from online PLC group teachers. Online group teachers' low participation limited the development of the PLC and did not allow the teachers to engage in in-depth dialogues and collective learning. Therefore, work needs to be done to explore strategies that can facilitate engagement and interaction of the online PLC group. It will be also valuable to investigate individual teachers' commitment and group dynamics and how those factors are associated with the effectiveness of PLCs.

In this study, the online PLC sessions did not happen as the principal investigator had anticipated. This study provided little information about the online PLCs, and it is unclear why online group teachers' participation has faded away. Therefore, future studies are needed to further explore online and hybrid PLCs and their effectiveness and limitations. Such studies should investigate different sets of facilitation strategies and individual teachers' characteristics (e.g., openness to learning, orientation to learning, etc.) and how those variables are related to the effectiveness of online PLCs. In addition, future research should consider investigating facilitator's behavior (e.g., how to work effectively with adult learners) because it can influence differently on the changes in teachers' attitudes and beliefs toward science teaching and the quality of PLCs.

Finally, in this study, the investigator did not consider individual teachers' preferences or needs and randomly assigned the teachers to either face-to-face or online PLCs. However, it may be worth customizing PD based on individual teachers' learning style, preference, or needs when deciding the format (e.g., face-to-face, online, hybrid, etc.) and content (e.g., content-focused, pedagogy-focused, both content and pedagogy-focused, etc.) for PD experiences. If we can identify each teacher's own gaps in specific content and pedagogy, we can provide more customized PD experiences that fill those gaps. At the end of the PLC sessions, one of the face-to-face group teachers expressed her challenge with less experience and education in early childhood. Another teacher shared her challenge with finding the time to implement the activities in a meaningful way in the classroom. The face-to-face group teachers also suggested using a discussion board online, reflecting more on research and articles, and connecting them to their teaching strategies in the classroom. Therefore, providing PD experiences that are geared to each teacher's need may be effective. It will be interesting to investigate the effectiveness of customized PD on teacher practices and child learning.

Implications for Practice

When educators have a better understanding of how to support children's science learning, they can teach science to young children more effectively. Such science professional development, in turn, will contribute to improving teaching quality and child learning. This study provided a greater understanding of PLCs for science education in preschool settings and showed that the PLCs could be used as a means to support teacher practice and child learning. PLCs can provide opportunities for teachers to engage in collaborative, reflective, and inquiry-based conversations about their science teaching and children's learning. Teachers working and learning together in a supportive, comfortable, and collaborative environment seemed capable of building a quality PLC that enhanced their knowledge, skills, and practices and children's learning with a minimal level of facilitation.

Effective science professional development seems to occur when it promotes PLCs at the program/school level as well as at the individual teacher level. The programs/schools can provide time and space for meetings among teachers and support PLCs in a comfortable and collaborative environment. Empowering and connecting teachers at the program/school level can serve as an innovative way to improve teachers' sense of community and teaching quality. In addition to the support from program/school directors/principals, individual teachers also need to investigate their own needs in specific content and pedagogy and then look for opportunities to fill those gaps.

Finally, opportunities for synchronous interactions and a knowledgeable and skillful facilitator seem necessary to make PLCs successful. In addition, it seems critical to help participants become comfortable in online learning environments before implementing the online PLC if it is necessary to create asynchronous online PLCs.

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APPENDICES

Appendix A

Teacher Demographic Survey

1. What is your job title?
- ○ Lead Teacher
- ○ Assistant Teacher
- ○ Other (please specify):

2. The total number of years you have taught in preschool?

[ ] Year(s) (Include this year)

3. Do you have a Child Development Associate (CDA)?
- ○ No
- ○ Yes
- ○ Working on one

4. Do you have an early childhood teaching certificate?
- ○ No
- ○ Yes
- ○ Working on one

5. What curricular approaches do you use in your classroom? (*Check all that apply*)
- ☐ Creative Curriculum/ Teaching Strategies GOLD
- ☐ High/ Scope
- ☐ Montessori
- ☐ Project-based approach
- ☐ Other (please specify):

6. Do you have a science area(s) or center(s) in your classroom?
- ○ No
- ○ No, but have science materials (list the science materials or activities):
- ○ Yes (list the science materials or activities in your science areas):

7. How often do you provide the science activities in your classroom (either as an activity during free-choice time or as a small/large group activity)?
- ○ Once a month
- ○ Twice a month
- ○ Once a week
- ○ Twice a week
- ○ Daily

8. Have you received any training related to teaching science?
- ○ No
- ○ Yes (specify major):

9. Are you currently receiving any training related to teaching science?
- ○ No
- ○ Yes (specify major):

10. What is your ethnicity or national origin? *(Check all that apply)*
- ☐ African American, Black
- ☐ American Indian, Native American, Alaskan Native
- ☐ Native Hawaiian or other Pacific Islander
- ☐ Asian
- ☐ European American, White
- ☐ Latino/a, Hispanic or Hispano
- ☐ Middle Eastern or Arab
- ☐ Bi-racial/multi-racial

11. What is the highest education level you have completed? (*Circle only one*)
- ○ High school diploma
- ○ Community college or equivalent; CDA (specify major):
- ○ B.A./B.S. degree (specify major):
- ○ M.A./M.S. or professional degree (specify major):
- ○ Other (specify major):

Your Contact Information

Center Name & Address:			
Your First Name:		Your Last Name:	
Your Phone Number:			
Your E-mail Address:			
Contact Preference:	○ Email	○ Phone	
Good Time to Contact:			

This page will be removed from the survey and kept separately by the research staff.

Thank you!

That completes my questions. I greatly appreciate the time you have taken to complete this survey.

Appendix B

Preschool Teacher Attitudes and Beliefs toward Science (P-TABS)

Please indicate the degree to which you agree or disagree with each statement below.

	Strongly Disagree	Mildly Disagree	Neutral	Mildly Agree	Strongly Agree
1. Preschool science activities help foster children's interest in science in later grades.	○	○	○	○	○
2. I feel comfortable planning and demonstrating classroom activities related to physical and energy science topics (e.g., force of gravity; gas, liquids, solids).	○	○	○	○	○
3. More science should be taught in the early childhood classroom.	○	○	○	○	○
4. It is important for my classroom to have a science area that can be freely explored by children.	○	○	○	○	○
5. Given other demands, there is not enough time in a day to teach science.	○	○	○	○	○
6. Experimenting hands-on with materials and objects is how young children learn best.	○	○	○	○	○
7. Science-related activities help improve preschoolers' approaches to learning.	○	○	○	○	○
8. I discuss ideas and issues of science teaching with other teachers.	○	○	○	○	○
9. I use all kinds of classroom materials (e.g., blocks, toys, boxes) for science activities.	○	○	○	○	○
10. Preparation for science teaching takes more time than other subject areas.	○	○	○	○	○
11. I use resource books to get ideas about science activities for young children.	○	○	○	○	○
12. I feel comfortable doing science activities in my early childhood classroom.	○	○	○	○	○
13. I feel comfortable planning and demonstrating classroom activities related to life science topics (e.g. living things, plants, animals).	○	○	○	○	○
14. Science-related activities help improve preschoolers' math skills.	○	○	○	○	○

15. It is not appropriate to introduce science to children at an early age.	○	○	○	○	○
16. Science-related activities help improve preschoolers' language skills.	○	○	○	○	○
17. I do not have enough scientific knowledge to teach science to young children.	○	○	○	○	○
18. I feel uncomfortable using scientific tools such as scales, rulers, and magnifying glasses when teaching science lessons.	○	○	○	○	○
19. I feel uncomfortable talking with young children about the scientific method (e.g., making hypotheses, predicting, experimenting).	○	○	○	○	○
20. I use the internet to get ideas about science activities for young children.	○	○	○	○	○
21. Young children cannot learn science until they are able to read.	○	○	○	○	○
22. I get ideas for hands-on activities from what my preschoolers do, say, and ask.	○	○	○	○	○
23. Science-related activities are too difficult for young children.	○	○	○	○	○
24. I include some books about science during storytime.	○	○	○	○	○
25. Science-related activities help improve preschoolers' social skills.	○	○	○	○	○
26. I enjoy doing science activities with my preschool children.	○	○	○	○	○
27. I am afraid that children may ask me a question about scientific principles or phenomena that I cannot answer.	○	○	○	○	○
28. I demonstrate experimental procedures (e.g., comparing objects to see if they will sink or float) in my classroom.	○	○	○	○	○
29. I do not mind the messiness created when doing hands-on science in my classroom.	○	○	○	○	○
30. Planning and demonstrating hands-on science activities is a difficult task.	○	○	○	○	○

31. Young children are curious about scientific concepts and phenomena.	○	○	○	○	○
32. I do not have enough materials to do science activities.	○	○	○	○	○
33. I make an effort to include some science activities throughout the week.	○	○	○	○	○
34. I feel comfortable planning and demonstrating classroom activities related to earth science topics (e.g., sun, moon, stars, weather).	○	○	○	○	○
35. I collect materials and objects to use in my science teaching.	○	○	○	○	○

Appendix C

Online PLC Participating Teacher Survey (Online)

1. When did you log into the Online PLC sessions over the past two weeks? *(Check all that apply)*

- ☐ Monday
- ☐ Tuesday
- ☐ Wednesday
- ☐ Thursday
- ☐ Friday
- ☐ Saturday
- ☐ Sunday

2. Where did you log into the PLC sessions over the past two weeks? (*Check all that apply*)

- ☐ Center
- ☐ Home
- ☐ Other (please specify):

3. What work did you do during the PLC sessions over the past two weeks? (*Check all that apply*)

- ☐ Opened the file(s) uploaded by the facilitator
- ☐ Opened the file(s) uploaded by other teachers
- ☐ Uploaded the file(s) (e.g., reflections, materials, lesson plans, etc.)
- ☐ Read postings (e.g., in online discussion forum, etc.)
- ☐ Uploaded postings (e.g., in online discussion forum, etc.)
- ☐ Replied postings (e.g., in online discussion forum, etc.)
- ☐ Commented on other teachers' work
- ☐ Other (please specify):

4. How long, in total, did you stay logged into and participate in the PLC sessions over the past two weeks?

- ○ Less than 0.5 hour
- ○ Between 0.5 – 1 hour
- ○ Between 1 – 1.5 hours
- ○ Between 1.5 – 2 hours
- ○ More than 2 hours

Appendix D

Preschool Teacher Survey (Post-PLCs)

1. How have you changed after participating in this PLC group (i.e., face-to-face or online sessions)?
2. What were the benefits to participating in this PLC group (i.e., face-to-face or online sessions)? Why?
3. What were the challenges to participating in this PLC group (i.e., face-to-face or online sessions)? Why?
4. How can the PLC sessions (i.e., face-to-face or online) be improved? What suggestions would you have?
5. Any further comments?

Appendix E

P-TABS Subscales and Items

Subscale	Item	Example
Teacher comfort		
	1. Comfortable doing science activities	"I feel comfortable
	2. Collect materials, objects for sci teaching	planning and
	3. Comfortable plan/demonstrating earth sci	demonstrating classroom
	4. Use all kinds of materials for sci activities	activities related to
	5. Include science throughout the week	physical and energy
	6. Enjoy doing science activities	science topics (e.g., force
	7. Comfortable plan/demonstrating life science	of gravity; gas, liquids,
	8. Use resource books to get ideas	solids)."
	9. Include science books during story time	
	10. Comfortable with physical/energy science	"I use all kinds of
	11. Discuss ideas, issues with other teachers	classroom materials (e.g.,
	12. Demonstrate experimental procedures	blocks, toys, boxes) for
	13. Use internet to get ideas	science activities."
	14. Get ideas from what kids do, say, ask	
Child benefit		
	1. Science improves approaches to learning	"Science-related activities
	2. Science improves math skills	help improve preschoolers'
	3. Science improves language skills	approaches to learning."
	4. Sci activities foster interest in science later	
	5. More science should be taught in classroom	"More science should be
	6. Science improves social skills	taught in the early
	7. Science activities too difficult for children	childhood classroom."
	8. Young children are curious about science	
	9. Hands-on is how children learn	
	10. Young children can't learn sci until can read	
Challenges		
	1. Don't have enough knowledge to teach sci	"Given other demands,
	2. Uncomfortable talking about sci method	there is not enough time in
	3. Afraid children ask a question can't answer	a day to teach science."
	4. Not enough time in a day to teach science	
	5. Preparation for sci teaching takes more time	"I do not have enough
	6. Plan/demonstrating science is hard	scientific knowledge to
	7. Don't have enough materials to do science	teach science to young
		children."

Appendix F

Science Teaching Ideas Developed by Teachers

Children's Interests/ Science Activity (Area):
mixtures/Potions. meseaurement of liquids (volume) / Sounds from glass jars.

How to talk about it (think about a way to explain):
• hands on experimentation — / trail & ERROR
more/less
mixture — adding two items together needs to be stirred most times
vibration
force
sound pitch < low / high
soft / loud
making a change to physical property.

How to set up it (e.g., how to set up science areas):
H2O
hair jell
droppers
measuring cups.
test tubes
bottles.
glitter
alkaseltzer
conditioner
jelly/o
glass jars filled with different levels of water
add color to H2O for visual

Children's Interests/ Science Activity (Area):
animals (living things) & plants
★ texture + appearance (aesthetic beauty)
length, weight, volume, etc. measurement

How to talk about it (think about a way to explain):
how something looks or feels is a characteristic of that object or living thing.
When we look closely at an object we can notice things about how it looks.
When you feel an item you can learn more about it.
Observe - look closely at something

How to set up it (e.g., how to set up science areas):
- an area with a variety of textures, colors for children to explore.
- tools for observation such as a magnifying glass or microscope for close exploration
- an area for viewing outdoors to observe in
- an area for collecting "treasures" or found objects for close observation
- display of photographs of items at actual size and then under a microscope
- Some art materials to create aestheticly pleasing creations

Children's Interests/ Science Activity (Area):

Weight: Scales

How to talk about it (think about a way to explain):

Introduce heavy and light and equal
When both sides are the same they are equal
When one side is up it is lighter

How to set up it (e.g., how to set up science areas):

Children will explore placing objects on the scales
Teacher will use behavior reflection as children explore
Teacher will introduce content as children discover how the scale moves
Teacher will ask question to extend thinking (what if I put this here?)

Children's Interests/ Science Activity (Area):

Bugs - Fish - Ants

How to talk about it (think about a way to explain):

We have new items in our science area
- you can watch them, ants and fish stay in containers
can touch Bugs
use magnifying glass.
See if they change over time
Read books about these - what they need. How they grow
Make charts - guess

Ask ?'s

How to set up it (e.g., how to set up science areas):

Display in appropriate "homes" - habitat
Add science tools - magnifying glass
food
life cycles

Appendix G

Face-to-Face Group Teachers' P-TABS Means and Paired Samples Test

		Mean (*SD*)			*t*-value		
		Time 1	**Time 2**	**Time 3**	**Time1-2**	**Time2-3**	**Time1-3**
Teacher Comfort (1 to 5)	**Cloy**	3.14	3.93	4.64			
	Megan	3.21	-	4.29			
	Emily	3.21	3.79	4.79			
	Joy	3.86	4.50	4.57			
	Mean (*SD*)	**3.36 (*.34*)**	**4.07 (*.38*)**	**4.57 (*.21*)**	-10.58*	-2.17	-6.07*
Child Benefit (1 to 5)	**Cloy**	4.90	5.00	5.00			
	Megan	4.30	-	4.80			
	Emily	4.00	4.30	4.90			
	Joy	4.60	4.60	4.80			
	Mean (*SD*)	**4.45 (*.39*)**	**4.63 (*.35*)**	**4.88 (*.10*)**	-1.51	-1.51	-2.37
Teacher Challenge (1 to 5)	**Cloy**	3.43	3.71	1.86			
	Megan	3.14	-	1.71			
	Emily	2.14	2.43	2.14			
	Joy	2.57	1.71	2.00			
	Mean (*SD*)	**2.82 (*.58*)**	**2.62 (*1.01*)**	**1.93 (*.18*)**	.25	.97	2.41

Note. Time 1 refers to the time before the workshop. Time 2 refers to the time after the workshop and before the PLC sessions. Time 3 refers to the time after the PLC sessions. Megan's P-TABS score was not included at Time 2 because she did not attend the workshop due to a family emergency. *p < .05. Possible range is from 1 to 5.

Appendix H

Online Group Teachers' P-TABS Means and Paired Samples Test

		Mean (*SD*)			*t*-value		
		Time 1	**Time 2**	**Time 3**	**Time1-2**	**Time2-3**	**Time1-3**
Teacher Comfort (1 to 5)	**Kate**	4.86	4.64	4.64			
	Kelly	4.07	4.36	4.71			
	Lilly	3.86	3.86	3.93			
	Betty	4.93	4.93	4.57			
	Mean (*SD*)	**4.43 (*.54*)**	**4.45 (*.46*)**	**4.46 (*.36*)**	-.17	-.12	-.16
Child Benefit (1 to 5)	**Kate**	4.20	4.20	4.20			
	Kelly	4.10	4.20	4.20			
	Lilly	3.40	3.40	3.50			
	Betty	4.30	4.30	4.20			
	Mean (*SD*)	**4.00 (*.41*)**	**4.03 (*.42*)**	**4.03 (*.35*)**	-1.00	.00	-.52
Teacher Challenge (1 to 5)	**Kate**	2.14	2.86	1.71			
	Kelly	1.86	1.86	1.57			
	Lilly	3.29	3.43	3.14			
	Betty	2.57	2.86	2.43			
	Mean (*SD*)	**2.46 (*.62*)**	**2.75 (*.65*)**	**2.21 (*.72*)**	-1.85	2.61	3.66

Note. Time 1 refers to the time before the workshop. Time 2 refers to the time after the workshop and before the PLC sessions. Time 3 refers to the time after the PLC sessions. *$p < .05$. Possible range is from 1 to 5.