BOUNDARY CROSSINGS BETWEEN PROFESSIONAL COMMUNITIES: DESIGNING ONLINE COLLABORATIVE LEARNING OPPORTUNITIES FOR INFORMAL STEM EDUCATORS

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Abstract

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Crossing Boundaries Between Professional Communities: Designing Online Collaborative Learning Opportunities for Informal STEM Educators

Dissertation directed by Associate Professor Erin Marie Furtak

Informal STEM educators, teaching in out-of-school environments, have few opportunities for professional development. These educators often have widely varied professional backgrounds and areas of expertise, which can lead to rich opportunities for learning with and from other informal STEM educators in the context of professional learning communities. In this dissertation, I draw on the concept of *boundary crossings* as a framework to understand how summer STEM camp instructors share experiences from their other personal and professional communities as they work together in a series of bi-weekly online professional development meetings designed to support them in enacting high quality informal STEM teaching practices. Drawing on a design-based research approach and using qualitative analytic methods, I share the results of this study through cross-case analyses of individuals' participation embedded within a single critical case of the professional learning community.

Findings indicate that online professional development meetings with activities designed to engage participants in discussion and reflection around common and emergent problems of teaching practice do serve as sites for learning. Analysis of the data focused first on identification of instructors' shared prior or concurrent experiences as evidence of potential boundary crossing activity, and then on the potential of those boundary crossing episodes to serve as sites of

learning through sociocultural differences that lead to change in participation or practices. Instructors in this project shared prior or concurrent experiences based on teaching experiences more than from other professional communities. Professional development activities based on emergent problems of practice resulted in boundary crossing episodes that informed instructors' teaching practices more so than activities focused on more abstract teaching concepts.

Implications for these results support the expansion of online, longer-term, facilitated professional development opportunities as a way of supporting year-round and seasonal informal STEM educators in the development of high-quality teaching practices. These findings also imply that the purposive formation of professional learning communities of instructors with varied professional backgrounds can provide rich resources for development of informal teaching practices and the design of informal learning environments that build on young peoples' interests.

Dedications

I dedicate this dissertation to my daughters, Hailey and Paige. Their endless wonder and curiosity about the world never fail to inspire me. Their giggles and hugs remind me to always look for the joy and love in every situation.

I also dedicate this dissertation to my mother, Sandi Guinn. Though she passed away long before I even started this journey, her support and encouragement were felt every step of the way. She would have joyfully read every word of every draft had she still been with us.

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RESEARCH PURPOSE AND BACKGROUND

Over the last 15 years, science learning that takes place outside of the formal school environment has become more recognized and valued as an important factor in increasing scientific literacy (National Research Council [NRC], 2009; Falk & Dierking, 2012; Feinstein & Meshoulam, 2014). There is rising acknowledgement in both research and practitioner settings that people learn science not only in school classrooms, as children, but also in informal settings such as museums, aquariums, botanical gardens, after-school programs, summer camps, and in the course of their everyday lives (NRC, 2009; Rennie, 2014). Over the course of an average lifetime, most people will spend less than 20% of their waking hours in a formal learning environment (Banks, et al., 2007). So where else do people, young people in particular, learn science besides a school classroom? The National Research Council's (2009) report on learning science in informal environments identifies three main "venues" where science learning commonly occurs outside of schools: *Everyday Settings and Family Activities*, *Science Learning in Designed Settings* (e.g. museums, science centers, aquariums), and *Programs for Young and Old*. This dissertation is situated in the latter category, focusing on out-of-school time programs for children facilitated by informal science educators, but is informed by research on teaching and learning from the other science learning environments, including K-12 schools and museum settings.

Key to the quality of out-of-school time programs are the informal science educators who are most often responsible for the design and enactment of the curriculum (NRC, 2015; Peter, 2009). Informal science educators teaching in out-of-school time programs come from highly varied backgrounds, often drawn to the field by the overlap of professional or personal

experiences in science and an interest in sharing that background with children (Bevan and Xanthoudaki, 2008; Cole, 2006; NRC, 2015). Depending on their specific educational goals, program coordinators hire informal science educators from a widely cast net, drawing from pools of university students, pre-service or in-service K-12 teachers, and current or former science professionals, among others. These widely varied backgrounds can serve as a rich pool of resources in learning environments that intentionally draw on young people's individual interests to inspire learning in the form of participation in designed science, technology, engineering, and math [STEM] activities. Despite the benefit that these non-traditional educational and personal backgrounds can provide in informing curriculum design and teaching practices of informal science educators, there is currently little to no opportunity for professionals in this field to reflect on or share their knowledge and practices. There is a robust lineage of research on the benefits of professional development for K-12 classroom teachers (Desimone, Porter, Garet, Yoon, & Birman, 2002; Luft & Hewson, 2014), but far less research focusing on professional development opportunities for informal science or STEM educators, particularly those working in afterschool or summer camp programs (Ash & Lombana, 2012; Bevan & Xanthadouki, 2008; NRC, 2015; Peter, 2009). While being cautious about claiming that what is good for K-12 classroom teachers will also be beneficial to informal science educators, the relative lack of research in this area indicates a need to identify, provide, and study professional development models for this important, but underserved population of educators.

One possible model of professional development that is widely used with K-12 classroom teachers is the formation of and participation in a community of practice organized for discussion and reflection on the enactment of teaching practices. In the context of formal education, communities of practice typically consist of education professionals, such as administrators and

classroom teachers, who are physically located together at a school site, meeting regularly to engage in reflection, planning, and discussion around teaching practices and student learning (Blitz, 2013; Little, 2003; McLaughlin & Talbert, 2001). Teachers reflecting on problems of practice in the context of a group setting with shared purpose have been shown to be productive in terms of student learning (Ash, Lombana, & Alcala, 2012; Furtak et al., 2016; Little, 2003).

While some informal science educators, such as those that are centrally located at a single informal science education institution such as a museum or science center, have the physical opportunity to meet in a central location by virtue of those venues being their primary workplaces, other informal science educators like those employed to teach summer science camps may not be working at a central location while planning lessons, nor even typically when teaching, since summer camps are often spread out among available spaces. An additional challenge for informal science educators are their varied schedules. While many informal science educators consider themselves employed in that profession full-time during at least part of the year, about 40% describe themselves as part-time or seasonal employees (Cole, 2006). For those employed part-time as instructors in afterschool and summer camp programs, they may also hold other jobs or be students the rest of the time. The resulting challenges in scheduling pre-instruction training to part-time informal science educators typically results in the single-day or single-week trainings that include a multitude of lecture-style instruction focused on providing imminently needed skills and knowledge, with little or no opportunities for instructors to reflect on previous teaching experiences or for new instructors to have access to more experienced instructors in the program (Bevan & Dillon, 2010; NRC, 2015; Peter, 2009; Tran & King, 2007).

These varied backgrounds and employment statuses of informal science educators make online communities, that bring together instructors from multiple backgrounds and responsible

for multiple STEM programs, a promising option for engaging informal science educators in longer-term participation in group reflection and disrupting the more typical single episode training sessions required of them (Blitz, 2013; McLaughlin & Talbert, 2001; Peter, 2009). Online communities can take place in time frames outside of typical business hours and from any location with access to a reliable and robust internet connection, using such free, readily available, and often ubiquitous online tools such as Google Hangouts. The online environment can serve to break down barriers faced by informal science educators in engaging in synchronous and asynchronous interactions with other educators from the time that they begin working on curriculum development through their summer camp sessions.

Rahm, in her commentary article for a special issue of the *Journal of Research in Science Teaching* on learning science in everyday life (2014), states that an important question to ask in furthering research in the field is, "How can we make informal settings legitimate training grounds for teachers, but also of our students as researchers and designers of cutting-edge science teaching and learning innovation?" (p. 404). In order to engage students in positive STEM learning experiences, programs need instructors who understand how to design for and enact activities that engage students; instructors who ideally would also have real-life experience in the content areas in which they teach. Providing quality professional development for informal science educators teaching in out-of-school time programs was identified as one of six actions that can be taken by stakeholders in this area to develop and support productive programs (NRC, 2015). In this thesis, I share the design and facilitation strategies for an online professional learning community for the semester prior to and during the summer of STEM camps, in collaboration with a university-affiliated program called Science Discovery. The goal of this collaboration was to help informal STEM educators design or adapt curriculum and reflect on

past and current teaching practices in this out-of-school time STEM learning environment. I specifically refer to instructors at this program as STEM educators rather than science educators because the content areas taught encompass the broader scope of STEM fields, beyond science fields. I then examine the ways in which instructors share their prior experiences, leading to boundary crossing episodes, and look for evidence in the form of changes in teaching practice which suggest that boundary crossing episodes were sites for learning.

Teaching and Learning in Informal Science Education Spaces

There are a wide variety of options for learning science outside of a K-12 school classroom: science centers, natural history museums, botanical gardens, aquariums, after-school science programs, science fairs or community events, summer science camps, and independent study through libraries, media, and online opportunities. All of these fall into the category of informal science learning spaces as places where children have the opportunity to engage in STEM activities in ways that are typically less structured than a K-12 school classroom (NRC, 2009, 2015; Rennie, 2014). The range of structure across these spaces can vary widely depending on the goals of the programs or institutions however, from completely unstructured and "free-choice" (Falk, 2001) to programs facilitated by a professional educator that are designed around K-12 science standards (Avraamidou & Roth, 2016; Bevan & Dillon, 2010; Rennie, 2014). Bell and colleagues (NRC, 2009) categorize informal science education learning spaces into three types of "venues": 1. Everyday settings and family activities, 2. Science learning in designed settings, and 3. Programs for young and old.

The first venue, *everyday and family learning*, encompasses science learning that happens in the course of everyday life, such as through conversations with family and friends, or in the course of pursuing personal hobbies or interests. These types of science experiences are

typically driven by individual interests and are not guided by professionals, though in the case of children, may be guided by parents or other family-affiliated adults (NRC, 2009; Callanan et al 2013; Falk & Dierking, 2012). Participation in science learning in everyday life is largely sporadic and opportunistic, rather than as part of any planned event.

The second venue, *designed environments* (e.g. museums, aquariums, botanical gardens), on the other hand, are representative of learning experiences facilitated by professionals such as exhibit designers or informal science educators. Such institutions engage visitors by designing elements to make exhibits accessible for learners of all ages or by employing floor educators, like the Exploratorium's Explainers (Richardson, 2012), to interact directly with visitors and facilitate interactions with the exhibits (Allen & Crowley, 2014; Ash et al., 2012; Tran, 2007). Science learning in informal science institutions is different from that in other venues, because while the space is designed for learning, the experience is episodic and fluid, rather than continuous, as is the case with the third venue of science learning: *programs* (NRC, 2009).

The third venue, *programs for young and old,* is distinct from the first two venues for informal science learning because these programs typically have "an organizational goal to achieve curricular ends" (NRC, 2009, p. 173). Programs are typically led by a instructor with pre-designed activities in mind, and occur over a specified series of days or weeks, rather than being episodic, as is characteristic of museum visits or science in everyday experiences. Rennie (2014), in her chapter synthesizing research on learning science outside of school, dedicates a mere paragraph to the topic of out-of-school time programs, much of which directs the reader to alternate sources, citing lack of space. This omission in a chapter synthesizing research in the field of informal science education speaks to the complexity of this category of learning spaces, as these programs perch on the bridge between informal learning environments and school

classrooms in that they are typically continuous or long-running, facilitated by a professional educator, and focused on some form of content- or process-based goals (NRC, 2009), but where children are not evaluated for learning progress and where they have more agency in determining the activities in that setting. Programs for children in informal spaces could be after-school STEM programs, summer camps, citizen science programs, and homeschool classes. These programs can be physically located at museums, science centers, botanical gardens, local schools, community centers, libraries, or other community organizations. Programs often resemble school classrooms in their fundamental structure but are, ideally "learner-driven, identifying and building on the interests and motivations of the participant, and use assessment in constructive, formative ways…" (NRC, 2009, p. 173). The ultimate goal of most of these out-of-school time programs is to enrich young people's STEM learning experiences. One of the key aspects in doing so is to hire and support informal science educators, much as K-12 education attends to the professional development of teachers as a key aspect of effective education for students (Peter, 2009).

The informal science educators who design and facilitate programs, regardless of their physical location, are responsible for engaging program participants in ways that are primarily designed to spark individual interests (Bevan, 2013; NRC, 2009; NRC, 2015; Tran, 2007). However, as Tran & King (2007) note, "their backgrounds are varied, ranging from science experts to hobbyists, and that their credentials range from those with formal teaching certificates to those with no educational preparation at all" (p.131). These widely varied backgrounds can serve as a strength for making meaningful connections with both children and fellow informal science instructors, but also presents challenges in that informal science educators have little common understanding about best teaching practices (Ash et al., 2012; Richardson, 2012; Tran

& King 2007). Bevan & Dillon (2010) share the results of their research and others involved with the Center for Informal Learning and Schools (a consortium between the Exploratorium, UC Santa Cruz, and King's College London) that show that there is little difference between high quality facilitation strategies in informal or formal science classrooms. This is the basis for researchers who draw on professional development models designed for K-12 classroom teachers when designing professional development for informal science educators.

Professional development for informal science educators has not historically been a robust field of research (Bevan & Dillon, 2010; Tran & King, 2007). Museums, as the most visible of venues for informal science education, have long offered professional development programs for K-12 classroom teachers. Phillips, Finkelstein, and Wever-Frerichs (2007) did a survey of 523 informal science education institutions, of which 59% offered professional development for K-12 classroom teachers (both pre-service and in-service teachers). These programs typically are aimed at increasing teachers' content and/or pedagogical knowledge (Phillips et al., 2007) or increasing familiarity with learning opportunities associated with field trip visits to museums and science centers. Offered programs demonstrated a wide range of structure and time commitment, ranging from special one-time events (representing 44% of programs offered), multi-day workshops (25% of programs offered), ongoing "education connections" (23% of programs offered), coaching and classroom support (21% of programs offered), teacher institutes more than 40 hours long (16% of programs offered), professional development provider training (15% of programs offered), and teacher internships (13% of programs offered). While these types of programs have been demonstrated to be beneficial to K-12 classroom teachers in supporting their teaching of science, the development of individual

science identities, and confidence with the discipline-specific content, there is little in the way of similar opportunities offered for informal science educators.

The most notable and broadly reaching professional development opportunity for informal science educators is the Informal Learning Collaborative [ILC], a product of the Center for Informal Learning and Schools [CILS] (Bevan & Dillon, 2010). The ILC provided multi-year professional development programs for informal science educators designed to help them design professional development for K-12 classroom teachers at their own institutions. These 5-day professional development workshops involved the participants engaging with scientific phenomena, observing others both on the museum floor and in informal classroom spaces, and engaging in discussion about learning theories with leading scholars Barbara Rogoff and George Hein.

Other models of professional development for informal science educators have largely been based on Schön's (1983) model of reflective practices, where educators engage in "thoughtful discussion and introspection, individually, within small groups, and through large group dialogue, focusing on what has been observed, and what the museum educator learned about their own role" (Ash et al., 2012, p. 24). Ash and colleagues (2012) used a community of practice model of professional development, with a focus on reflective practice, to transform museum educators' interactions with museum visitors as they engaged with floor exhibits. The pedagogical goal was for educators to approach visitors with the understanding that visitors came to the museum with individual knowledge and experiences and for the educator to informally assess what visitors knew and help them move towards a more scientifically complete understanding of the phenomenon being observed, through Vygotsky's zone of proximal development (1934/1987). Another method of professional development for informal science

educators is to engage them in conducting research themselves, as DeGregoria Kelly (2009) did with a group of zoo educators. Results from her study indicated that participation in action research projects increased the ability of the educators to self-assess their instructional and other job-related practices.

More recently, the landscape of opportunity for informal science educators has included programs such as Reflections on Practice, developed and led by Lynn Tran at the Lawrence Hall of Science, which works in partnership with informal science institutions to train existing staff members on how to be professional development leaders at their own institution (Harty & Nava, 2018). This model is unique in that it engages informal science educators in the context of their own communities, while providing them with high-quality professional development opportunities facilitated by a more-experienced, trained colleague who is supported in their facilitator role by researcher who are also practitioners. Programs like this are more frequently available within individual institutions or on a regional basis, but once again, are focused on educators embedded in informal science institutions. With the relative easy and availability of the internet, other programs such as Click 2 Science PD offer asynchronous module-based models of professional development, available free of charge for informal science educators or educator-trainers. While the modules developed and shared by this organization do offer professional development opportunities for informal science educators, including those who work in after-school or seasonal situations, they do so in a de-contextualized manner, leaving individual users to the task of making connections between abstract concepts and their own settings for teaching.

Across the relatively small body of research on informal science educator professional development, a primary goal has been to shift instruction away from traditional, didactic,

transmission models towards learner-driven and situated pedagogies inspired by constructivist learning theory (Bevan & Xanthoudaki, 2008; Ash et al., 2012; Tran & King, 2007; Zhai, 2015; Richardson, 2012). Those who study and implement such professional developments have focused on changing epistemologies of learning in informal science educators as a way of beginning to change practices. However, such work is most effectively done in environments where professional development can be implemented over longer periods of time. Thus it is important to note that the vast majority of the empirical and theoretical research literature found that relates to professional development for informal science educators is for those who work in a museum or museum-like setting, rather than those who work in after-school or summer camp settings.

There are two primary aspects to consider when thinking about learning in informal spaces that are relevant to the design of professional development for informal science educators. The first is how the student activities are designed, and the second is how educators respond to students during classroom interactions. When informal science educators write curriculum for their classes, they need to be designing lessons that allow students agency in their own learning. Bell (2013) says there is "a long history of empirical studies [that] has documented the educational assets that all learners bring to learning experiences and the educational possibilities associated with helping youth develop increased degrees of freedom to navigate their life as they so choose." (p. 96) This agency is a hallmark of informal science learning spaces. Informal science learning spaces should provide students with opportunities to expand on individual interests, within the context of the group activity (NRC, 2015). Bell and colleagues (NRC, 2009) identify high-quality STEM activities as "learner-motivated, guided by learner interests, voluntary, personal, ongoing, contextually relevant, collaborative, nonlinear, and open-ended

(p.11). As such, learning environments need to have options for activities that are open-ended, but still able to be accomplished within the scope of a particular time period and with certain materials, and that provide opportunities for students to engage in science and engineering practices (Board on Science Education [BOSE], 2012), per the described program goals. At the same time, instructors need to be capable of recognizing that students come to these classes with knowledge and skills and that they, as educators, should be able to informally assess where each student is on the spectrum of relevant knowledge and facilitate their experiences in the classroom space in responsive ways. In the next chapter, I describe the conceptual framework I draw on in order to address these challenges faced by informal STEM educators.

CHAPTER II

CONCEPTUAL FRAMEWORK

Sociocultural and Situative Learning Theories in Out-of-School Time STEM Environments

Research in out-of-school time environments has drawn strongly on sociocultural and situative views of learning, attending to individuals' actions in the context of the designed learning environment as evidence of learning. Taking a situative view on learning means that researchers must build on and look beyond constructivist views, more common in the decades leading up to the turn of the century, that considered learning as the integration of new pieces of content knowledge with prior existing knowledge in the mind of an individual. Constructivist theories of learning have been adapted to include the idea that learning may also occur as a result of social interactions (Vygotsky, 1987). Thus, situative perspectives consider learning to be a cognitive process that takes place in a social context, focusing on the role that participation of individuals in social interactions plays in the development of new knowledge at varying levels of analysis (Greeno & Engeström, 2014).

From a situated perspective, learning is viewed as taking place in context and through interactions with others through joint problem-solving activity (Greeno & van de Sande, 2007). While not discounting the cognitive view that learning is the process of the individual building structures of knowledge in the mind (Piaget, 1972), here I focus on the concept that learning is the result of interactions with other people engaged in similar or complimentary tasks, each individual bringing to the interaction their own varied expertise (Greeno & Engeström, 2014). Learning in such contexts is defined as the construction of knowledge based on patterns of

participation and changes in practice as a result of those interactions. The situated perspective can explain learning on both the individual and group planes of analysis. Interactions between participants in such groups result from the individual experiences and expertise of the participants and the designed activities of the community. The integration of these experiences and shared materials into personal repertoires of teaching practice then become evidence of learning that occurred as a result of those social interactions with other community members.

Wenger (1998) further developed this view of situated learning by studying how learning occurs as individuals became more central participants in communities, and how individual identities develop within the context of those communities. Participants may position themselves in different ways in the various communities which can result in different forms of participation in each, leading to individual identities within each community. In professional learning communities, learning occurs as participants draw on individual or group knowledge to co-construct shared patterns of reasoning as a regular and recurring activity centered around a shared context (Greeno & Engeström, 2014). Researchers then study interactions among group members rather than, or in addition to, reports of an individual's thinking in order to understand how different pieces of the system or infrastructure contribute to observed changes in practice or participation (Ash & Rahm, 2012; Greeno, 2006, Greeno & Engeström, 2014, Hall & Jurow, 2015). Learning occurs as participants draw on individual or group knowledge to co-construct shared patterns of reasoning as a regular and recurring activity, and these activities become part of the group's infrastructure (Greeno & Engeström, 2014; Hall & Jurow, 2015). Depending on the context of the interaction, participants may leverage different experiences from different communities. Thus, researchers taking a situated perspective consider all the physical and interactional aspects that occur in a particular situation, looking for changes in participation and

changes in individual and group practice as evidence of learning in shared spaces, including dialogue between participants, availability and use of resources, affordances and constraints of the physical environment, activity structures, and the individual identities or expertise brought to the particular setting by the participants (Greeno & Engeström, 2014; Wertsch,1998).

Overviews of research in informal science education have identified the predominance of sociocultural and situative theories of learning in empirical studies across informal science environments (Ash & Rahm, 2012; Osborne & Dillon, 2007; Rennie, 2014; NRC, 2009, 2015). Conducting research in such fluidly structured environments does not lend itself to the more traditional methods of research on learning, such as administering individual assessments on learning, nor do these less structured environments lend themselves to more common methods of research on teaching, given the challenges of gathering informal science educators together in traditional types of professional development groups (e.g., professional learning communities; McLaughlin & Talbert, 2001). Informal environments are characterized by their less-structured settings, which results in both affordances and constraints for researchers, instructors, and learners.

Informal science learning environments are largely differentiated from K-12 classrooms in that participants are there of their own free choice and expect to engage in STEM activities using a greater number of resources than are typically available and with greater freedom than is typically allowed in K-12 classrooms. There is a focus by researchers in such environments to treat learning as a cultural practice, making it possible to use methods and ask questions that help us understand these environments where learning occurs in a less linear manner, in a more nuanced way (Ash & Rahm, 2012). As Penuel & O'Connor (2010) point out, early studies around communities of practice and the movement of participants towards mastery assume a

relatively straight trajectory within a static community of practice. This is not the context facing researchers in informal science environments, who work in fluid environments with flexible activity structures, who work with informal science instructors entering a community at various life and professional stages, in a profession often treated as transitory, and where logistical complications such as work schedules make a static community of practice challenging to maintain. Considering learning from more fluid perspectives will help researchers understand the myriad puzzle pieces that play a part in learning in these complex out-of-school time environments.

In the following sections, I will first discuss the ways in which informal STEM instructors draw on situated theories of learning when designing activities for science programs that take place in out-of school time environments, such as after-school programs or summer camps. I will then build on this practice of informal science educators to discuss how facilitators of professional development for informal science educators can draw on situated learning theories in designing learning environments that support these educators while they develop curriculum and reflect on teaching practices in a shared environment.

The Design of Productive Informal STEM Learning Environments

STEM learning environments should engage students in first-hand experiences with phenomena and materials that draw on and build from their personal experiences or community, that allow them to investigate phenomena of interest in proximity to other young people, and to have the opportunity to share their investigations (NRC, 2015). Programs with goals such as these are intentionally designed to engage young people in activities using practices similar to how professionals in STEM fields do their work. With this overarching goal in mind, how can curriculum designers draw on situated learning theory to design for productive learning in out-

of-school time environments? To answer this question, I first consider what productive learning looks like in an out-of-school time setting at the program level, then discuss qualities of good STEM activities used within those programs to engage learners.

The goals of out-of-school time STEM programs, while varying from program to program, are largely intended to generate young people's interest in STEM by engaging them in authentic, first-hand, open-ended activities. Jolly and colleagues (NRC, 2015) identified three main criteria for productive STEM out-of-school programs, all of which are emblematic of a situated theory of learning in how they foreground the social aspects of the learning environment. The first criterion is that programs must "engage young people intellectually, academically, socially, and emotionally" (p. 2). Productive programs should provide first-hand experiences that engage young people in ongoing STEM practices within the context of a supportive learning community. The second criterion is that programs be responsive to the interests, experiences, and cultural practices of the young people involved. This criterion speaks in particular to how young people in informal STEM programs are positioned as primary agents in their learning, more so than typically occurs in K-12 classrooms. Programs that are responsive to young people try to position them in situations where they can collaborate and take on leadership roles, and to take care to position staff, not in the role of knower, but rather as a collaborator and learner alongside the program participants. The third criterion identified in the NRC report is that programs should connect STEM learning across settings, such as school, home, after-school or other out-of school time programs, informal science institutions, and learning that occurs in other everyday settings. High quality programs will use young people's' experiences across these settings and leverage them for increased participation and learning. In addition, the report specifies within the context of this third criteria, that programs should act as

brokers for additional STEM learning opportunities. All three of these main criteria for productive out-of-school time STEM programs foreground the social aspects of learning rather than discipline specific content acquisition, identifying learning as engaging with other young people around first-hand STEM activities. Programs that identify themselves as STEM, but do not design activities that value engagement, responsiveness, and connections, are not going to be productive learning environments for young people (NRC, 2015).

How do these program-level criteria then translate into the design of productive out-of-school time learning environments? Bevan & Dillon (2010) identify features of "high-quality informal science learning activities" (p. 177) as those that position science as a means to achieve a desired purpose rather than as an end unto itself, that create multiple pathways to account for varying levels of prior knowledge and experience, that use tangible materials and phenomena to invite participants to explore, and that help participants connect the science content with real-world problems or settings. These characteristics, which overlap with those identified in the NRC report (2015), highlight the social aspects of young people learning by engaging in social activities, specifically science activities that are relevant to everyday life and asks learners to not just assimilate new knowledge, but to actively use it to solve real-world problems.

Such activities are developed or adapted on an as-needed basis, by informal science instructors or curriculum development staff. They often draw on existing resources, but rarely use scripted curricula. However, Rennie (2014) is careful to distinguish that just because activities are occurring in an informal environment doesn't mean that they don't need to be structured. She notes that it is the context of the learning environment that is informal, not the learning itself. Thus, designers of such experiences need to be thoughtful about critical aspects of the offered activities. One example is that curriculum designers for informal learning spaces need

to take into consideration the varying levels of experience that different young people might bring with them into the shared learning space and choose activities that can be adjusted to engage them at a variety of knowledge levels and with materials available to the those who want to go beyond the initial boundaries of the proposed activity.

This constant innovation in curriculum design allows out-of-school time STEM programs to respond to the changing landscape of STEM fields and the interests of specific groups of young people working together in such programs. These planned activities, much like lesson plans in K-12 classrooms, are intended to help young people further their knowledge of natural phenomena through a process of investigation and first-hand experiences. Ideally, curriculum designers would choose or develop activities that will help young people iterate on their success and failures, that will put program participants in a position to discuss and share results with others, that will provide access to additional resources and materials, and will allow young people to get positive and actionable feedback about their ongoing projects. In order to design and enact meaningful curriculum, informal science educators need to understand the connection between how young people can learn science in social situations and how activities developed or chosen for informal science programs can afford or constrain those positive and productive interactions.

Learning Theory for Professional Development of Informal STEM Educators

In many out-of-school time programs, it is the informal science educator who is largely responsible for both developing and implementing curriculum. However, as noted in the NRC (2015) report, informal science educators often haven't had the opportunity to learn about different theories of teaching and learning that are a critical underpinning in the education of pre-service K-12 teachers. Typical training for out-of-school time educators, when it exists, is often

a single day or week-long training focused on logistical aspects of program operation rather than on improving instructional practices or designing for productive social interactions among instructional staff. When instructors don't have ongoing opportunities to engage in reflective discourse around teaching practices, they tend to use more didactic methods of instruction. They tend towards teaching as they themselves had been taught in school, substituting "hands-on" activities as a constructivist-based method for transmitting scientific content (Bevan & Xanthadouki, 2008).

The field of informal science education, while historically based on constructivist theories of building individual structures of knowledge, has more recently taken up situated theories of learning, and is now beginning to apply those theories of social learning to developing programs to train both K-12 teachers and informal science educators. Over the last decade, there have been more frequent opportunities for informal science educators to engage in professional development. When available, professional development opportunities for informal science educators focus on developing communities of educators, over long time periods, who have the opportunity to discuss common problems of practice and develop shared language (e.g., Reflections on Practice Program at Lawrence Hall of Science; Informal Learning Collaborative at The Exploratorium: Bevan & Dillon, 2010). However, these projects are typically aimed at educators working in institution-based environments, rather than those employed to teach seasonally, as is more typical for summer STEM camp educators.

The NRC (2015) report states that "to support productive and responsive teaching and learning in out-of-school settings and programs, program staff need opportunities to develop their ability to nurture young people's interests and understanding of STEM content and practices." (p. 46). Jolly and colleagues (NRC, 2015) identify the following effective

components of professional development for out-of-school time STEM instructors: taking advantage of staff expertise, offering ongoing opportunities for rehearsal and feedback, offering opportunities for ongoing individual development of discipline-specific content knowledge and skills, allowing for time to cultivate collaboration among instructional staff, and augmenting training with additional resources and materials. These characteristics of effective professional development allow instructors to learn from and with each other, within the context of an active teaching practice, with the support of their administrative staff both in terms of providing paid time and additional resources, materials, and possibly access to facilitators with expertise in fields relevant to informal STEM education, such as educators and practicing scientists. Professional developments such as those described here are designed to help instructors learn as part of a community, drawing on the prior experiences and expertise of people whose widely varied professional backgrounds could be a strength or asset in a field of education focused on learning in social environments.

In education, situative theories of learning are often used to describe how K-12 teachers learn and reflect on teaching practices, in groups with other teachers, through participation in a professional learning communities approach to professional development (Ash et al., 2012; McLaughlin & Talbert, 2001; Wenger, 1998). In such communities, teachers who teach similar subjects or grade levels come together at regular intervals to meet and discuss problems of practice. Such problems might include co-development of lessons plans (curriculum), discussions around student assessments, or reflections on the effectiveness of particular teaching techniques (instruction). Generally speaking, productive communities go through cycles of planning, enactment, reflection, and re-design (Furtak & Heredia, 2014; Hewson, 2007). Facilitators of community-approach professional development should draw on the needs and

resources of each community however, resulting in unique designs for the enactment of the professional development (Hewson, 2007). I draw on these characteristics of professional development to understand how informal educators employed to teach summer STEM camps might be able to learn about teaching practices using a professional learning community approach to professional development.

Boundary Crossings in a Community of Informal STEM Educators

As stated above, the individuals employed as instructors in informal learning environments are not only educators, but come from a wide variety of other personal and professional communities as well. Oftentimes, summer STEM camp instructors do not consider themselves as professional educators, but rather are engaged in other professions as their primary occupation during other seasons of the year. These individuals, professional educators and seasonal educators alike, bring differing repertoires of expertise with them into a potential community around teaching in summer STEM camps. Wenger (1998) described this kind of participation in multiple professional communities as "constellations of practices" (p. 126): communities that have related goals and intersecting memberships, but that may not be officially connected in any way. Akkerman and Bakker (2011) describe such groups as being "...heterogeneous in nature in that they involve multiple actors representing different professional cultures." (p. 134). This intersection of experiences that instructors bring from other professional or personal communities, while engaged in a group focus on the development of curriculum and discussion around best teaching practices in informal STEM environments, result in some experiences and knowledge that overlap as well as some that differ widely. It is in this intersection of experiences that researchers look for evidence of learning as a result of shared ideas and resources, which Star (1988) identified as "boundaries".

When used colloquially, a boundary refers to a dividing line between two demarcated spaces, such as the border between two cities. In Star's conception, boundaries refer to the overlapping areas of two or more communities, as in a Venn diagram. Akkerman and Bakker (2011) describe boundaries between two or more communities as a "sociocultural difference leading to discontinuity in action or interaction". It is within this overlap, or boundary, that there is potential for learning to occur, as a result of that discontinuity. Akkerman and Bakker further identify four mechanisms of learning that can occur as a result of boundary crossing: identification, coordination, reflection, and transformation. Each of these four mechanisms describes a different process whereby learning in boundary crossings occurs. These mechanisms of learning, while not intended to be hierarchical or sequential, can be used to discriminate between individual and group contributions, and the integration of those contributions. Thus, it is important to consider both how individual participants share their experiences and how the group, composed of said individuals, do or do not take up the contributions when investigating learning in boundary spaces.

Participants who bring their individual experiences in one community to bear on problems faced by a different community have been labeled as boundary crossers or brokers in prior literature (Akkerman & Bakker, 2011; Akkerman & Bruining, 2016; Bakx, Bakker, Koopman, & Beijaard, 2016; Cobb, McClain, Lamberg, & Dean, 2003; Polman & Hope, 2014). While these terms are used somewhat interchangeably, here I distinguish them based on the scope of the research. When I refer to "boundary crossers", I mean those participants who have crossed into a boundary space, bringing their expertise from one community into another community. For this study, I created and used the phrase "home community" to refer to the primary personal and/or professional community in which informal STEM instructors spend the

majority of their time during the part of the year that they are not teaching in informal contexts. By explicitly identifying the home communities of instructors, I position them as potentially valuable resources for learning about practices in communities different from one's own, while also acknowledging that these participants are likely to leverage experiences from other communities as well, given their identities as members of multiple communities.

There is a unidirectionality in my use of the term "boundary crossers" in that the flow of resources is discussed as to how resources are brought into and taken up in a shared community, but not in how participants in a focus community may or may not be boundary crossing in the other direction, to their 'home' community. The focus of research drawing on a boundary crossing framework is generally on the challenges faced by professionals as they engage in activities with other professionals originating from disparate 'home' communities, in the context of an overlapping community or boundary space (Akkerman & Bruining, 2016; Bakx et al., 2016; Cobb et al., 2003; Penuel, Allen, Coburn, & Farrell, 2015; Suchman, 1994).

However, when I use the term "broker", I focus more often on the bridging of two or more communities. Brokers are those individuals who are able to establish membership, however peripherally, across two communities, moving back and forth between the communities and providing a unique link between them (Akkerman & Bruining, 2016; Cobb et al., 2003). To some degree, there is an intentionality in brokering activities, where the design or intent of the intervention is to bring the resources of one community into another, and possibly back again (Akkerman & Bruining, 2016; Polman & Hope, 2014). Researchers look to understand how brokers exist in multiple communities or what ideas and resources they are sharing between the two, thus adding a bidirectionality or multidirectionality to the focus of their studies.

Broadening the scope of consideration beyond the participants in boundary spaces, Star (1988) also described how inanimate objects can transit between communities. She coined these items as boundary objects: ideas or resources that are brought from one community to another by boundary crossers or brokers. Star defines boundary objects as "objects that are plastic enough to be adaptable across multiple viewpoints, yet maintain continuity of identity" (p. 243). Thus, a boundary object can be brought to a community by one or more members, having been used in disparate ways in those 'home' communities, but come to have a shared meaning or purpose in the focus community. They are artifacts of the group process that have then been incorporated into the practices of two or more communities (Cobb et al, 2003). These objects are not necessarily tangible, but can be ideas or words as well. Boundary objects can serve as points of disruption in communities, creating opportunities for critical discussions as group members seek to reconcile different conceptual practices. The results of engaging in such discussions can lead to the development of new practices or social arrangements, or as Hall and Jurow (2015) describe it, new representational infrastructures. Hall and Jurow define representational infrastructure as the "technologies, ways of talking, and the materials that support how people engage with conceptual practices in their activity." (p.174)

In environments such as a community of informal STEM educators, it is valuable to highlight and draw on the individual experiences and resources that participants bring with them from other communities that they have been or are currently members of, but with the recognition that such differing experiences might result in interactional challenges, or boundaries, between participants. Within the context of a professional learning community for informal STEM educators, there might exist instructors who are practicing scientists and thus participate within that community, there might be secondary science teachers who also

participate in teacher learning communities at their own school, and there might be parents working part-time who is able to share insights from parent communities.

Therefore, in designing a learning environment for these kinds of educators with widely varied backgrounds, such an environment would necessarily involve boundary crossing, as instructors engage in discussions around best practices. While boundary crossings occur in both new and established communities, how members of individual communities intersect in a nascent professional learning community can be particularly productive in understanding the benefit of such communities and in informing the design of future meetings. Facilitators of such communities can broker potentially productive interactions by explicitly inviting participants of varied professional backgrounds to reflect or respond during conversations. Following Star's (1999) concept of representational infrastructure, by inviting participants to understand and make visible their individual infrastructures, a facilitator can broker potential boundary crossings. Such infrastructures, for a teacher or informal science instructor typically include the invisible aspects of everyday practice, such as the guidelines of the institution in which one teaches, the availability of materials, one's own reasons for working in a profession, ways of talking, technologies, and other resources (Hall & Jurow, 2015). Many of these pieces of infrastructure only become visible when explicit attention is called to them or they break down, thus inhibiting the ability to accomplish the work in question. In the case of a nascent community, such as the one studied in this project, one person's infrastructure could be another participant's challenges. In bringing to light and working through such differences, participants can be seen as boundary crossers and the ideas or resources that they bring to the group to share from their other communities can be conceived as boundary objects, if taken up by other instructors and integrated into individual teaching practices.

However, given the scope of this study focusing on a single nascent community, it was not possible to observe participants acting as brokers, as I did not have access to their 'home' communities. The focus of this study was the boundary crossing activities of participants in a designed boundary space, and following participants back into their teaching spaces to observe how they potentially leveraged incidences of boundary crossing in the professional development meetings to build on their individual teaching practices. By taking a boundary crossing perspective, I acknowledge that teaching in K-12 schools, teaching in informal environments, and engaging in scientific experimentation are socially and culturally different. This perspective allowed for the study of challenges and opportunities for learning as a result of the establishment of new relationships and a new culture with respect to the development of curriculum and teaching practices in summer STEM camps.

Bringing Informal STEM Educators Together in a Professional Learning Community

Communities in which professionals work together in a designed social setting towards a shared goal can be productive sites of learning (Akkerman & Bruining, 2016; Cobb et al, 2003; Wenger, 1998). Informal science instructors brought together in such settings can draw on their individual professional experiences in other communities to negotiate understanding of the pedagogy behind, and the development of, quality curriculum for young people enrolled in out-of-school time programs. As these communities present potential sites of learning for informal science educators, such encounters can be designed and facilitated to maximize the opportunity for instructors to act as boundary crossers, drawing on experiences in other aspects of their personal and professional lives to engage in discussions and negotiations about teaching practices and the design of learning environments. The opportunity to interact with other instructors who likely bring differing experiences with them, can serve to enrich or disrupt

teaching practices by allowing instructors to examine and support their understanding of best practices with other instructors, and then to independently draw on those discussions when designing and enacting curriculum for the out-of-school time programs for which they are responsible.

To explore these interactions, I conducted a research study with instructors employed to design curriculum for and teach in summer STEM camps. I adopted a situative view of learning to investigate how informal STEM educators worked together in an online community to reflect on teaching practices, problem-solved emergent challenges, and designed quality curriculum for young people enrolled in summer STEM camps. I used the concept of boundary crossings to see how summer camp instructors leveraged their individual experiences and prior knowledge in a series of shared professional development meetings, designed to encourage interactions between participants as the primary source of new knowledge, rather than didactic transmission of information from the facilitator. I acted as both the designer and facilitator of this professional learning community. In addition to investigating how interactions in a designed group setting resulted in new shared understandings of teaching and learning in out-of-school time learning environments, I observed instructors enacting their planned curriculum, to look for ways in which the instructors may have taken up those shared understandings in their individual teaching practices.

Research Questions:

1. How do participants leverage experiences from their 'home' communities as they participate in a learning environment designed to prepare them to teach in a summer STEM camp?

2. What types of boundary crossings occur in this environment, and in what ways did these crossings serve as sites for learning about high-quality informal STEM teaching practices?
3. How did boundary crossings in the professional development meetings inform instructors' teaching?

CHAPTER III

RESEARCH DESIGN AND METHODOLOGY

Overview of Study Methods

The purpose of this research was to investigate how instructors from different professional communities engaged in boundary crossing activities in an online professional development setting as they prepared to teach in summer STEM camps. To understand how instructors engaged in and took up this work, I designed and facilitated a series of five online professional development meetings for a focus group of seven summer STEM camp instructors and then subsequently observed the instructors in their summer camps as they enacted their curriculum with children. To establish the ways in which participants acted as boundary crossers from their 'home' communities, I collected multiple sources of data, including interviews, video recordings of the professional development meetings, artifacts from meetings, original and refined curriculum, and observations of selected teaching enactments in summer camp. In the following sections I will explain the context of the study, the design of the professional development meetings, descriptions of collected data, and the analytic approach used to answer the research questions.

Preliminary Supporting Work - Virtual Teacher Learning Community

During the 2014-15 school year, Erin Furtak and her research team conducted the virtual Teacher Learning Community Project [vTLC], a year-long online professional development program for a group of new and experienced secondary science teachers (Swanson, Furtak, & Buell, 2016). The focus of the meetings, as mutually negotiated between facilitators and participants, was the Next Generation Science Standard [NGSS] (BOSE, 2012) practice of developing and using models, particularly as used for formative assessment. Findings indicated

that participants were able to form a community of practice (Wenger, 1998) using online video conferencing tools, across various levels of teacher experience, grades, and disciplinary subjects.

The vTLC project showed that participants were able to collaborate in an online environment using Google Tools to work towards a shared goal, including sharing student work, readings, and other resources. The most frequent Google Tool used was Google Hangouts, followed by the sharing of documents in Google Drive, making comments and sharing online links using the Chat function, and less frequently, doing a screenshare so that other participants could see what one participant was doing. Together, the use of these online tools allowed the group to complete two iterations of the Formative Assessment Design Cycle [FADC], which guides teachers through cycles of designing, enacting, and reflecting upon formative assessments used in their respective classrooms (Furtak et al., 2016). Use of a guiding tool such as the FADC provided teacher participants with experience and feedback in the design and implementation of formative assessments.

Study Context and Pilot Project

While presenting a poster on the vTLC project in the fall of 2015, I was approached by Brian Jernigan, the new director of the Science Discovery summer STEM camp programs. Science Discovery is a university-affiliated program serving young people in the Denver Metro area since 1983. Their summer camp program serves over 1700 local children each summer, offering approximately 250 camps for children between the ages of 5-18 years, with the bulk of camps serving children aged 13 and under. Camps range in duration and topic, from engineering with Legos to creating nature notebooks. Most camps are offered half day, either morning or afternoon, for a one-week time period. Camps occur at a variety of sites on and around the university campus, including at Science Discovery's own small building, in maker-type spaces

around campus, and out in natural environments such as nearby regional parks. Jernigan, like many summer camp program directors, was concerned about the ineffectiveness of current instructor training methods and was looking for new approaches to bringing instructors together prior to start of camps. The idea of providing an online version of training intrigued Jernigan, particularly with regards to vTLC's use of free online tools.

Erin and I worked with Science Discovery to write a successful grant to the University of Colorado Boulder's Office of Outreach and Engagement to collaborate in the design and enactment of a series of professional development modules. I began by interviewing ten returning summer STEM camp instructors. Analysis of my notes from these interviews yielded identification of four main topics to focus on during the professional development meetings:

1) Understanding the purpose and intent of STEM oriented learning environments
2) Curriculum development practices and resources
3) Classroom management practices and techniques
4) Development of a camp instructional culture

I developed a facilitation guide for each module containing a proposed timeline and guiding questions for the conversation. Each facilitation guide was developed sequentially, after reviewing field notes of the previous meeting and revisiting the analysis of the interview notes, so that the purpose of each meeting was reflective of prior discussions as well as moving the group of instructors towards the final goals of curriculum development and updated teaching practices.

For this pilot project, which occurred prior to the study being described in this thesis, I recruited instructors via email from a list compiled by Science Discovery of 14 potential participants who had previously worked for this organization either as an instructor or as a

teaching assistant. Further communication between instructors and myself who expressed interest and availability yielded a group of six participants. Each of the four meetings was 1.5 hours long and took place roughly every two weeks between April and May of 2016. The participants and I met in the online environment using Google Hangouts and Google Drive. Meeting attendees included myself, as facilitator, 4-6 Science Discovery Instructors hired to teach STEM camp programs in Summer 2016, and Brian Jernigan. To encourage ongoing discussion and reflection on teaching practices and curriculum design, the instructors were invited to a private group on Google +, through which they were encouraged to post ongoing questions, concerns, or experiences while leading summer camps; however, this forum for discussion remained unused. Science Discovery staff and I continued to meet about once a month to discuss ongoing program challenges and to reflect on the usefulness of the professional development modules. During these meetings, there was substantive feedback shared between stakeholders about the design possibilities for a second iteration of the professional development the following summer, with the ongoing intent to develop a sustainable set of modules that could be facilitated by program staff or former participants acting in leadership roles.

On the basis of these two prior projects, I proposed an extension of this partnership with Science Discovery to develop and implement a revised set of modules for the preparation of summer STEM camp instructors, with a focus on curriculum design and reflection on teaching practices.

Research Design

I used an embedded case study approach to answer the research questions posed above (Yin, 2003). The professional development meetings represent a single critical case in which I drew on existing literature on the design and enactment of professional development methods for both K-12 and informal educators to engage individuals in learning about high-quality STEM

teaching practices. The individual instructor participants are then considered as embedded units of study within the single case of the group context. However, I present the findings as cross-case analyses of interactions between individuals resulting from participation in the group meetings, to understand how this designed environment does or does not provide opportunities for instructors to learn about teaching practices (Yin, 2003). Evidence of such learning opportunities was observed in changes in participation or practice.

Participants. The participants in this study were recruited from instructors employed by Science Discovery to design curriculum and teach summer STEM camps in the summer of 2017. Science Discovery employed 68 instructors during for the Summer 2017 camp season, who collectively taught 229 camps. While a few of the instructors teach for Science Discovery year-round, the majority were hired to teach only during the summer camp season.

Instructor recruitment. Science Discovery summer STEM camp instructors were recruited from job postings sent to local school districts, university job boards, university teacher education programs, university content-area STEM programs, and through word-of-mouth. Hired instructors were typically graduate students in STEM or related fields, current or pre-service K-12 teachers, former scientists or teachers looking for part-time employment, adjunct professors, or very experienced STEM undergraduates (B. Jernigan, personal communication, November 17, 2016). Most instructors had some affiliation with the university prior to or while working for Science Discovery.

Recruitment for study participants. Participants recruited for this study were asked by Jernigan in an online survey if they would "be interested in participating in a collaborative effort between the School of Education and Science Discovery to support best teaching practices?" (B. Jernigan, Personal Communication, January 27, 2017) Jernigan shared the names and email

addresses of hired instructors who had indicated "yes" or "maybe" on their initial surveys (N=12). All instructors who indicated interest received an email from me with the IRB-approved recruitment letter attached (see Appendix A), which explained the project and provided my contact information. Those who indicated further interest were asked to fill out an online survey describing their professional background and professional development needs (see Appendix B). The original intent of the survey was to allow me to gather enough background information to compose a purposive sub-sample of 6-8 persons with varying levels of teaching experience and backgrounds. Ten instructors filled out the survey, with seven of those eventually consenting into the study and completing Interview 1. Of the original seven consented participants, five remained in the study through completion. The final cohort of participants represented a variety of backgrounds, as described in Table 1 below.

Table 1

Final Cohort of Participant Instructors

Participant (pseudonym)	Primary 'Home' Community	Camp Subjects Taught	Returning Instructor
George	CS PD Research Team, Informal STEM Instructor, Retired Engineer	Video game design	Returning
Margaret	CS PD Research Team, Retired Computer Scientist	Coding using Scratch	Returning
Sarah	Geology Graduate Student	Geology field camps	Returning
Chris	Preschool Teacher	Field camp on ponds and streams	New

		Physics camps on vehicles Physics camp on building	
Alex	Secondary Mathematics Teacher	Math Lego EV3	New
Nicolaus*	Secondary Physics Teacher	Physics camp Engineering camp Spy camp	New
Matthew*	Secondary Social Studies and Maker Space Teacher	Stop motion animation	New

*Instructor did not remain in study through completion

I present instructors in the following order, unless otherwise stated, due to returning instructor status, similarities in camp subjects, and completion of the study: George, Margaret, Sarah, Chris, Alex, Nicolaus, and Matthew. All instructor names are pseudonyms to protect the identity of study participants.

Design for the learning environment. As described in the literature review, few examples exist for facilitating a learning environment in this context. I drew heavily on previous professional development communities that I had participated in and/or facilitated, on information about instructor needs based on interviews of the consented participant instructors, and on productive professional development activities supported by research.

Recommendations for effective professional development models that came out of research studies in K-12 contexts suggest that meetings should be long-term, embedded in practice, reflective, collaborative, and facilitated (Desimone et al., 2002; Luft & Hewson, 2014;

Opfer & Pedder, 2011; Schon, 1983; Zhang, Lundeberg, & Eberhardt, 2011). Thus an ideal professional development model applied to this context would include meetings that were ongoing, beginning prior to the start of summer camps and continuing at least through the completion of the instruction, would include participants who had similar professional development needs, would include tasks which had the instructors iterating between individual reflection on practice, collaborative discussion and curriculum design, and implementation of discussed or designed practices.

Building on the approach and outcomes of the 2016 pilot project, the proposed main topics of the modules in the design phase were: (a) understanding the purpose and intent of STEM-oriented teaching and learning environments, (b) curriculum refinement and resources, (c) development of positive classroom culture, and (d) identifying and problem-solving challenges of teaching in informal learning spaces. These topics were chosen based on the needs identified by instructors interviewed prior to the first meeting, shared reflections by instructors and facilitators from the pilot project on the productiveness of the enacted meeting topics, and strongly informed by research on existing programs for informal science educators as described previously.

Drawing on design-based research methods in which interventions are designed, studied, and then iterated on as appropriate in learning environments, I created content logs (five minute segments), which I used to adjust agendas for subsequent meetings to best meet participant and organizational needs (Brown, 1992; Penuel, Allen, & Coburn, 2015). Due to these reflections and iterations on the design of the professional development activities, I changed previously planned activities and resources to better serve this group of teachers. For instance, in Meeting 1 the group did a video observation and discussion activity using a publicly posted video from a

different organization, of children learning about the physics of motion in an informal learning environment. The instructors in this group expressed frustration at not being able to get more information around the context of the video. So during Meeting 3, I used video collected by Jernigan, with appropriate parent permission, during a 3-hour weekend morning Science Discovery class. Using this video proved more to be a more productive potential learning environment for instructors, as evidenced by the seven boundary crossing episodes that occurred relating to teaching during these activities and by comments made by participants during subsequent meetings and post- and follow-up interviews. One instructor, Sarah, was even observed during her instruction using a teaching strategy originally shown during the Science Discovery video. In addition to my reflections on each professional development meeting, participants were encouraged to communicate any feedback about their participation in the project with me, at any time. It was as a result of such feedback that I increased the number of shared research-based resources (e.g., Brown & Ryoo 2008 research article, Teacher Talk Moves resources from TERC) that I shared during and outside of the online meetings, always in our shared Google drive folder.

Drawing on prior studies indicating that some combination of active learning and explicit instruction is most helpful for teacher learning in professional development (Penuel, Gallagher, & Moorthy, 2011), these meetings included guided discussion of problems of practice around focal topics (e.g. classroom talk structure, teacher talk moves) as well as focused readings, video observations and discussions, opportunities to reflect on individual teaching practices (e.g. Think & Shares), dissection of existing Science Discovery curriculum, and opportunities to share emergent challenges. Table 2 outlines the original activities planned for each meeting, while Table 3 shows the enacted activities. Changes in originally planned activities were made based

on the creation and analysis of meeting content logs, which occurred in the days following each meeting, and on feedback from the instructors regarding emerging needs and challenges. For example, the Icebreaker activity was not one that I had originally planned, but was added in response to a suggestion by one of the participants that such activities help build friendships. In the tables below, activities are listed in the order in which they would occur chronologically within an individual meeting, always starting with Introductions or Check-Ins first.

Table 2

Planned Activities for the Professional Development Meetings

Proposed Activity	Description	Meeting			
		1	2	3	4
Introductions /Check-ins	Begin each meeting with introductions or check-ins to help the group share their progress in camp planning.	X	X	X	X
Guided Discussion	Discussions based on specific, pre-identified topics guided by facilitator questions. (included Think & Share)	X			
Video Observation	Instructors will watch a video of a Science Discovery class and will reflect on the observed teaching practices and activity choices.		X	X	
Curriculum Dissection	Instructors will be presented with a lesson plan for a camp activity. They will then share their opinion of the curriculum as is and any suggested changes.		X		

Focused Readings	The facilitator will provide participants will readings based on a topic relevant to the group ahead of the meeting and ask participants to be prepared to discuss.	X			X	X
Resource Reflection	Group will collectively look at common resources for STEM activities and determine usability based on preferred characteristics.		X		X	

Table 3

Enacted Activities in Professional Development Meetings

Enacted Activity	Description	Meeting				
		1	2	3	4	5
Introductions /Check-ins	Begin each meeting with introductions or check-ins to help the group share their progress in camp planning.	X	X	X	X	X
Icebreaker	Group plays an activity designed to allow participants to get to know each other better.		X			
Guided Discussion	Discussions based on specific, pre-identified topics guided by facilitator questions. (Included Think & Share)	X			X	
Video Observation	Instructors will watch a video of an out-of-school time STEM class and will reflect on the observed teaching practices and activity choices.	X		X		

Curriculum Dissection	Instructors will be presented with a lesson plan for a camp activity. They will then share their opinion of the curriculum as is and any suggested changes.	X			
Focused Readings	The facilitator will provide participants will readings based on a topic relevant to the group ahead of the meeting and ask participants to be prepared to discuss.				
Resource Reflection	Group will collectively look at common resources for STEM activities and determine usability based on preferred characteristics.	X	X	X	
Brainstorm	Group will share emergent challenges and collectively discuss potential solutions.				X

A more detailed text-based description of the design and enactment of the activities in the professional development meetings can be found in Appendix C-1, with meeting facilitation guides found in Appendix C-2.

The study began with a series of meetings between Science Discovery staff and myself to co-design goals and agendas for at least four online meetings, based on our shared reflections of the outcome of the first iteration of professional development modules and on information about instructor needs from interviews of consented participant instructors. The professional development meetings, which included the instructors and myself as facilitator, occurred every 2-3 weeks between late March – early May 2017, as determined by participant availability, with an intentional gap between the conclusion of the meetings and the start of camps, to allow time

for data reduction and analysis prior to the second set of individual interviews and the instructor teaching observations.

The professional development meetings took place in an online Web 2.0 environment, using the Google suite of tools (i.e. Google hangouts, Google drive, etc.). Online environments are a potential solution to the challenge of gathering informal science educators together in one place, during a time of the year when they are often employed or engaged in daily activities elsewhere. Blitz (2013) identified the following as common foci for professional learning communities for educators: development of lessons, gains in student achievement due to instructional practices, and to identify professional learning needs. MacLeod (2010) found that the presence of a facilitator was key to the overall experiences of in-service teachers' participation in online professional development. These studies informed the design of this community, in both the topic focus and enactment, with deference to the differentiated needs of informal science educators

As designer, facilitator, and researcher, my decisions played a significant role in shaping interactions during the meetings. Many of these decisions were intentional and included aspects of the design, such as the topics, activities, and resources shared. Table 4 below outlines the topics and designed activities that occurred in each meeting, with further detail about justification process for the design of each meeting provided in Appendix C-1. As previously stated, meeting topics were chosen based on a combination of factors, but on a more specific level, I intentionally varied between topics that were more pedagogically-based, such as characteristics of good summer camps, with those that were more practice-based, such as classroom talk structure. However, regardless of the type of topic chosen, activities were designed to provide the instructors' with opportunities to notice and reflect on their own and

other's teaching practices. I intentionally engaged in facilitation practices that introduced dissonance into the conversation to provoke sharing and discussion, including acting as a broker, being the only person in the group who was familiar with the backgrounds of all participants. For example, one of the videos we observed together as a group showed an out-of-school time instructor giving a start-of-activity talk in a more lecture-style manner. I selected that video because I'd hoped it would elicit instructors noticing a type of teacher talk that did not align with their own views of good teacher practice. In addition to design decisions, as facilitator during the meetings I also would play "devil's advocate" and ask questions that I knew did not align with existing recommendations on pedagogical practices in order to provide participants with the opportunity to make visible their own representational infrastructure and thinking. Other choices I made as a facilitator included sharing my own prior experiences as a teacher and summer STEM camp instructor as a way of prompting participants to share their own experiences, as well as drawing on my knowledge of instructors' backgrounds to ask them to share potentially different personal pedagogies of practice to introduce dissonance into the conversation and encourage boundary crossing activities.

Table 4

Topics and Designed Activities in the Professional Development Meetings

Meeting	Primary Meeting Topic	Designed Activities
1	Characteristics of good summer camps	● Introductions ● Think & Share ● Video Observation
2	Curriculum development	● Introductions/Check-ins

		• Dissecting Lesson Plans
3	Classroom talk structure and teacher talk moves	• Check-ins • Video Observation • Discussion: shared resources
4	Reasons for teaching STEM	• Check-ins • Think & Share • Discussion: shared resources
5	Emergent instructional challenges	• Check-ins • Discussion: Brainstorm • Individual instructional goals

Sources of Data

To respond to the research questions guiding this work, I collected data from a number of sources. In keeping with the design-based approach to this study, these sources of data were continuously analyzed through the project to improve the professional development meetings, through iterative cycles of design, so as to best prepare the instructors for their work in Science Discovery camps. Table 3 identifies the connections between my research questions, data sources, and my analytical approach.

Table 5.

Analytic Approach to Answering the Research Questions

Research Questions	Data Sources	Analytic Approach

1. How do participants leverage experiences from their 'home' communities as they participate in a learning environment designed to prepare them to teach in a summer STEM camp?	▪ Video recordings of PD meetings ▪ Instructor interviews ▪ Artifacts from PD meetings ▪ Field notes from PD meetings	➢ PD meetings transcribed and coded at the individual speaker level. ➢ Interviews transcribed and tracer* tagged ➢ Artifacts and field notes used to triangulate data from PD meetings and interviews.
2. What types of boundary crossings occur in this environment, and in what ways did these crossings serve as sites for learning about high-quality STEM teaching practices?	▪ Video recordings of PD meetings ▪ Field notes from observations and PD meetings. ▪ Instructor interviews ▪ Artifacts from PD meetings and refined curriculum	➢ PD meetings transcribed and coded at the individual speaker level. ➢ Interviews transcribed and tracer tagged. ➢ Summer camp observation field notes tracer tagged. ➢ Artifacts used to triangulate conclusions from PD meetings and interviews analysis.

3. How did boundary crossings in the professional development meetings inform instructors' teaching?	▪ Video recordings of PD meetings ▪ Summer camp observation field notes ▪ Instructor interviews ▪ Artifacts from PD meetings and refined curriculum ▪ Google+ posts	➢ PD meetings transcribed and coded at the individual speaker level. ➢ Interviews transcribed and tracer tagged. ➢ Summer camp observation field notes tracer tagged. ➢ Artifacts used to triangulate conclusions from PD meetings and interviews analysis.

** "tracer" tagging is defined on page 50*

Video recordings of professional development meetings. The primary source of data were video recordings of each of the five online professional development meetings. Recordings were made using QuickTime's screen recording feature, which captures all video and sound being streamed across the screen of a single computer. These recordings captured spoken and visual group interactions, any typed comments made in the chat function of Google, resources shared via screen sharing or being physically displayed, and any links shared.

Interviews. In order to more fully understand participant backgrounds and perspectives, I conducted a semi-structured interview of each participant prior to the start of the professional development meetings (pre-interview), an interview following completion of professional development meetings (post-interview), as well as a final interview after the instructor had completed their summer camp instruction (follow-up interview), for a total of three interviews

per instructor. Interview questions from the pilot project (see Appendix D-1) were adapted and expanded to include more substantive questions about the instructor's background and non-Science Discovery professional experiences and to ask more detailed questions about their current understanding of learning theory, particularly as it is applied in out-of-school time learning environments (see Appendix D-2 through D-4 for interview questions). All interviews were audio recorded and, for those participants that remained in the study, their interviews were professionally transcribed.

Artifacts from professional development meetings. I collected, in digital form, artifacts of all shared resources from the professional development meetings, for reference in understanding the basis of meeting discussions and curriculum development. Such artifacts included agendas, facilitation guides, lesson plans, resources such as websites, templates, and materials lists. These artifacts were downloaded and archived following each meeting.

Field notes. I took notes during the professional development meetings as backup to a technology failure and to record my personal observations on the occurrences in the meetings, as they occurred. These notes were largely unstructured, largely intended to help me remember topics to attend to before the end of the individual meeting. I supplemented these handwritten notes with my reflections, immediately following the meetings in research memos. These notes were supplemental to the video recordings. In addition, in the days following each meeting, I typed a summary of the meeting notes in a shared Google document accessible to the participants. These documents also served as a form of field notes in reflecting on the meetings.

Curriculum. In addition to collecting artifacts from the professional development meetings themselves, I requested access to final curricula, as submitted to Jernigan, from each instructor. These included lesson plans and supporting documents. I collected this curriculum as

a way to triangulate instructors' discussions and reflections on their curriculum development throughout the course of the meetings and while teaching.

Observations of teaching in summer STEM camps. I took detailed field notes while observing instructors teaching their summer camps during mutually agreed upon times. Handwritten field notes were typed up within 24 hours of each observation. The focus of these observations was on the actions of the instructor and his or her interactions with children and other camp staff. No identifying information about camp attendees was collected during the course of these observations.

Data Reduction and Analytic Approach

Using an embedded case study approach, I analyzed each data source, considering both the main case of the professional development group meetings and the individual participants. Data reduction and analysis began while the study was ongoing, with initial analyses used to inform the design of the professional development meetings and to collaboratively decide on instructor observation times. I conducted further analyses, to be described in a later section, after the completion of data collection, focusing on answering the research questions, rather than on the iterative and reflective design of the professional development meetings.

Analysis Completed During Data Collection. Given the design-based nature of the project in which this research is embedded, data processing and the initial rounds of coding took place as an iterative process. Pre-meeting interviews were transcribed and analyzed immediately following completion, using both deductive and inductive codes. Deductive codes were based on the questions asked, such as identifying background, teaching experience, and challenges in teaching. I developed inductive codes during the coding process in order to capture recurring themes and topics (Miles, Huberman, & Saldana, 2013). I analyzed these interviews to determine

the strengths and challenges of this particular cohort of instructors while considering the institutional goals. I developed meeting-specific facilitation guides and itineraries for each of the five professional development modules in advance of each meeting.

In the week following each professional development meeting, I watched the video-recorded meeting and created a content log in 5-minute segments that captured the main points of participant discussion. I adapted the facilitation guides for subsequent meetings based on events that happened in the previous meetings. I then subsequently used these content logs in the initial phases of analysis to develop the definition of boundary crossings that would be used on meeting transcripts, as described below.

I conducted the post-interviews in the weeks following the completion of the professional development meetings, but before the instructors began teaching summer camps. Post-interviews were transcribed and, in conjunction with the pre-interviews and content logs from the professional development meetings, used to identify possible topics or activities for observation. I emailed instructors individually with these identified topics or activities and asked them to suggest up to three specific one-hour time blocks during which I could come and observe their camp instruction.

Analysis in the Post-Data Collection Phase.

Identification and Coding of Boundary Crossings Episodes. Identifying boundary crossing episodes that occurred in the context of these professional development meetings was fundamental to all subsequent analyses in this research study. As such, I will describe in detail the process by which I identified boundary crossings that occurred in the professional development meetings. As mentioned above, the first step was to reduce each meeting to a content log, segmented into five-minute increments. Each segment included information on who

was speaking, the primary topic being discussed, and a summary of the flow of conversation. These content logs were coded using primarily inductive codes as a method for the development of the final codebook. Initial codes included *speakers, professional development activity, official topic of conversation, emerging topic of conversation,* and *sharing prior experiences*.

Operationalizing boundary crossings. Drawing specifically on excerpts of the content log coded as *sharing prior experiences*, as well as definitions of boundary crossings as described by Star (1988) and further defined by Akkerman & Bakker (2011), I developed an operational definition of boundary crossings. I presented this definition in a seminar of mathematics and science education colleagues and asked them to apply it to transcript excerpts that I had previously identified as being incidences of *sharing prior experiences.* Along with several examples that I did not think were examples of a participant sharing a prior experience, and thus not part of a boundary crossing episode. I refined my definition of boundary crossing based on feedback from that session and used the refined definition during a reliability check with a science education colleague. The final definition of boundary crossings used for coding was: *A boundary crossing is an instance, of undefined length, in which a participant explicitly draws on a prior lived experience.*

Reliability check. This definition was operationalized in such a way that all instances of boundary crossings were identified, regardless of whether or not the topic of discussion was about a mutual problem of practice. With a science education colleague, we did a reliability check on the identification of individual talk turns coded as *shared prior experiences.* A talk turn was identified as an independent segment of talk by one individual, bounded by talk by other people before and after. We independently coded the full transcript from Meeting 5, which included 361 talk turns between six instructors and myself. The Meeting 5 transcript was chosen

for reliability after being identified as having the highest number of potential boundary crossings after the initial analysis of the content logs. We had direct agreement on 336 talk turns (95.8%) and adjudicated our differences on the remaining 15 talk turns, seven of which were ultimately included in the total of 53 talk turns coded as *shared prior experiences* during Meeting 5.

Based on the high level of agreement between my colleague and me on identification of *shared prior experiences*, I coded the remaining four meetings. I then sampled the talk turns around each prior experience to capture the conversation that led up to and resulted from that shared prior experience, using shifts in topic to identify the beginning and end of the conversation. Each of these sampled sets of talk turns, as a group, constitutes a boundary crossing episode.

I sampled all talk turns coded as *shared prior experiences* to include the conversation surrounding the individual coded talk turn, which I then identified as a *boundary crossing episode (BCE)*. Each boundary crossing episode was assigned a unique identifier. There were a total of 172 shared prior experiences encompassed in 67 boundary crossing episodes. Figure 1 helps to visualize this coding and sampling process.

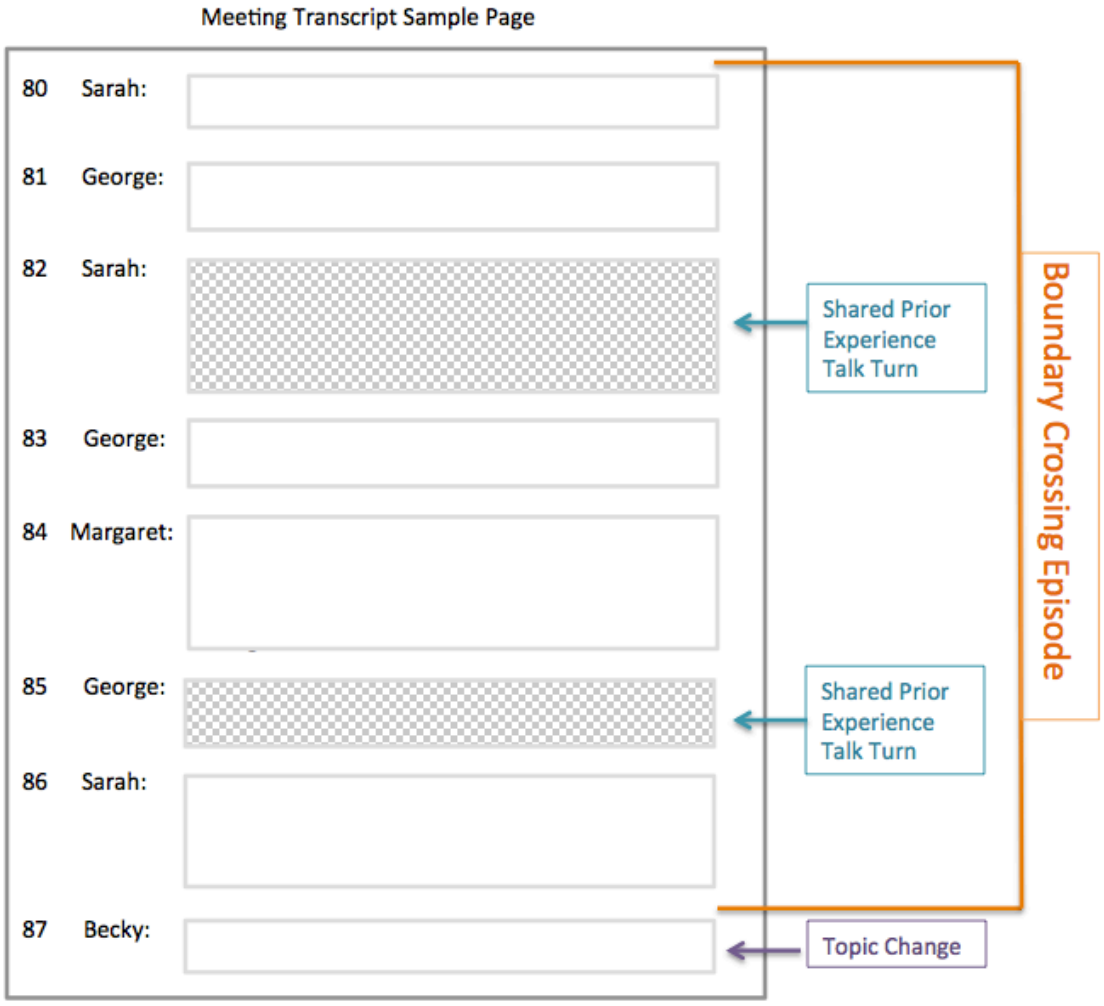

Figure 1. Sampling a Boundary Crossing Episode

Coding of Boundary Crossing Episodes. After all of the boundary crossings episodes were identified, I coded the following elements of each: *speakers, professional development activity, official topic of conversation, and emerging topic of conversation.* While some codes were deductive (e.g. *speakers, professional development activity*), the others were created during the coding process to reflect the topics that emerged during the conversation and were ultimately the basis for the tracer tags used for the interviews. Despite the focus of this study being on teaching practices of informal STEM educators, I did not filter participants' shared prior experiences or episodes of boundary crossing based on that criteria, so as not to artificially

constrain the results at this point of the analysis. However, the application of these codes did allow me to specifically identify boundary crossing episodes related to problems of practice in an informal teaching context.

Table 6

Codes Applied to Boundary Crossing Episodes

Code	Definition	Child Code Examples
Professional Development Activity	Activities directed by the facilitator during a PD meeting and which all participants present were asked to engage in.	Lesson Plan Dissection, Brainstorm, Think & Share
Official Topic of Conversation	Conversation topic identified in Facilitation Guide for Meeting	Curriculum Development, Teacher Talk Moves, Getting Campers Attention
Emerging Topic of Conversation	Conversation topic that emerged in the course of a meeting, most often as a sub-topic of the official topic of conversation	Lesson Plan Details, Icebreakers/Making Friends, Videotaping Lesson Enactments

Identification of Boundary Crossing Episode Topics Across the Chronological Data. While coding the boundary crossing episodes, I noted in my data log possible *tracer* words or phrases that could be associated with each episode. Tracer words or phrases, or "tracers" is a concept that originated in cognitive psychology research methods, in which the researcher

intentionally embeds "a bit of knowledge or some procedure" (Newman, Griffin, & Cole, 1984) in order to trace an idea across multiple contexts and persons. I, however, drew more strongly on Roth's (1996) use of Tracers as a way to understand how different types of knowledge, "facts and objects, laboratory skills, conceptual understandings" (p. 193) diffuse through an elementary classroom across multiple lessons.

Specific to this study, I first identified Tracers associated with teaching practices and those that emerged organically through instructor interactions during boundary crossing episodes. However, since the boundary crossing episodes chronologically occurred mid-study, I drew on Keefer, Zeitz, and Resnick's (2000) framework on student dialogues to identify significant Tracers in reverse. After identifying emerging topics of conversation and possible tracer codes from the boundary crossing episodes (see Appendix E for example of data log), I used a compiled list to begin the process of identifying those tracer codes across the other primary pieces of data, which included the interviews and teaching observations for each of the five participants that had participated in the entire study. I first backwards coded for Tracers, beginning with the final individual interview that took place following the completion of summer camp instruction (follow-up interview), then coded the teaching observations, the interview that took place between the PD meetings and the beginning of summer camp instruction (post-interview), and finally the interview that took place prior to the start of the PD meetings (pre-interview). During this coding process, I sampled excerpts related to Tracers derived from the boundary crossing episodes, as well as inductive Tracers that emerged during coding and were most often specific to individual participants. These Tracers were recorded in a spreadsheet data log, along with line number sample identifiers. In order to capture as many Tracers as possible, and to see the pattern of Tracers across an individual's data set, I then completed a second,

chronological pass of the data as I entered each sampled excerpt along with its associated Tracers into Dedoose.

Finally, in order to see the patterns of associations among the Tracers, I aligned the previously applied emergent topics and Tracers from the boundary crossing episodes with the Tracers from the interview and teaching observation data, to see the occurrence and frequency of Tracers that appeared across chronological data and across individual cases.

Analysis of Boundary Crossing Episode Types. In an effort to encompass as many possible boundary crossings, no reduction of data was made regarding the topic of the boundary crossings initially. Results from the intersection of the tracers applied to the interview and observation data with the emergent topics and tracers applied to the boundary crossing episodes resulted in the identification of nine boundary crossing episodes which had no tracer connections to the rest of the data. There was no obvious pattern among these nine boundary crossing episodes to indicate why the topics raised weren't taken up. They occurred in different PD meetings and involved prior experiences shared by five of the eight meeting attendees, and happened at different points within the meetings.

I then used the Emergent Topic of Boundary Crossing Episode and Tracer topics derived during the first cycle of data analysis to develop pattern codes which encompassed the types of topics that emerged (Miles, Huberman, and Saldana, 2014). During the first pass, I identified which boundary crossings related to teaching and which did not. For example, a boundary crossing episode about writing lesson plans was marked "yes", as relating to teaching, whereas a boundary crossing episode where the discussion was about the intelligence of crows was marked "no". As a result of this coding pass, 12 boundary crossing episodes were eliminated from further analysis. When cross-checked with the nine boundary crossing episodes identified as

having no tracer connections to the rest of the data (as described above), a total of 17 boundary crossing episodes were eliminated from the data set for either having no associated tracer codes relating to the rest of the data or for being unrelated to teaching, or both (see Appendix F). It is key to note that a high number of associated tracer codes did not mean that a boundary crossing episode was a critical one, but rather the tracers were used to allow me to identify where boundary crossings may have started prior to interviews and where topics might have progressed, as will be shown below.

The remaining 50 boundary crossing episodes were then sorted into four emergent categorical pattern codes: Teaching Practices, Logistics, Motivation to Teach STEM, and Socio-emotional Support of Students. Teaching Practices encompassed the broadest range of topics and tracers, including: strategies for engaging students, drawing on real-world challenges in activity design, teacher talk moves, classroom talk structure, teamwork strategies, STEM content, and formative and summative assessments for informal learning environments. The Logistics pattern code included topics such as: teaching assistants, classroom management, materials set-up, timing of the camp day, contact with parents, writing lesson plans (including prototyping activities), and attending to basic human needs (bathroom, food, temperature). The pattern code Socio-emotional Support of Students covered topics such as making new friends (icebreakers), facilitating student disagreement, and helping students work through failure. The final pattern code, Motivation to Teach STEM, included instructors' self-reflection and personal motivations around teaching.

Identifying home communities. Much like the identification of boundary crossings were fundamental to this study, understanding the personal and professional backgrounds of the participants, as they related to boundary crossing instances, was a critical aspect in tracing the

progression of each boundary crossing. 'Home' communities are defined as the primary personal and/or professional communities in which instructors spend most their time during the part of the year that they are not instructing summer STEM camps for Science Discovery. Participants were asked during the pre-interview to describe their personal and professional backgrounds. Home communities were identified based on their primary professional community outside of their work at Science Discovery. These identifications were aligned with statements coded as *sharing prior experiences* in the meeting transcripts and then triangulated with post- and follow-up interviews.

Validity and Reliability

I used several strategies appropriate for establishing the validity of methods used in case study research (Merriam, 1998), including: triangulation, long-term observation, peer examination, and clarification of research biases.

Triangulation. First, as part of the design of the study, I collected multiple sources of data in order to triangulate. The primary data used in triangulation included recordings of the professional development meetings, three semi-structured interviews for each participant conducted at critical junctures in the project, and observations of instructors teaching in their summer camps. Preliminary findings that emerged during the ongoing analyses of the professional development meetings, conducted throughout the project, were confirmed by multiple primary sources of data (e.g. interview and observation data), secondary sources of data (e.g. personal communication with participants, curriculum, and artifacts from meetings and observations), as well as by more detailed analysis of the data through a finer grained coding and tagging system, as described above. I also explicitly looked for, and shared in the findings, confirming and disconfirming evidence in individual cases in which boundary crossings did

(positive cases) and did not (negative cases) occur in the professional development meetings as a means for supporting the validity of my conclusions.

Long-term observation. While my engagement with participants in the meeting setting was not as long-term (e.g., continuing through summer camp instruction) as research on professional development recommends, I was involved with these participants on a weekly basis for five months. The frequency of contact over this time period allowed me to observe and interact with instructors repeatedly and thus identify patterns of behavior relating to preparing for and teaching in summer camps.

Peer examination. Initial and subsequently refined findings from this research were shared regularly with science education and learning sciences colleagues, as well as the summer camp program administrators beginning shortly before the start of the professional development meetings and continuing through this dissertation report. Settings for these peer examinations included one-on-one meetings and group presentations in both seminars and in peer-reviewed conference presentations. In all instances of peer examination, feedback was both requested and attended to, most often in the form of analytic memos regarding said feedback.

Clarification of researcher biases. In this type of study, where I acted as the designer and facilitator of the professional development meetings, and as the sole researcher, it is necessary to not obfuscate the role I played and how my intentions and actions may have affected the participation of the instructors. As such, I included the ways in which I participated in the professional development meetings and instances in which I acted as an intentional broker between communities. Admittedly, during the observation portions of the study, I struggled to remain an observer and not a science teaching coach, a role which blurred when I was asked by participants to give them feedback on their teaching enactments. I mitigated this blurring of roles

by taking detailed field notes on my interactions with instructors both during and outside of observations of instruction.

CHAPTER IV

FINDINGS

Overview of Findings

The findings of this study indicate that informal science educators draw on experiences from their home communities when working together towards a common goal in a professional learning community, but their offerings are mediated by their lack of familiarity with other participants, this being a nascent community, and by the virtual context of the online meeting. Participants draw more heavily on their teaching experiences than on those from their home community, which may or may not align, when asked to reflect on teaching practices. However, when asked to problem-solve, the rate of drawing on home communities as well as prior teaching experiences rises, suggesting that discussions centered around authentic and emergent problems of practice are more effective in creating potential for learning through dissonance in boundary crossings by engaging participants in discussion and in finding creative ways to address emerging instructional challenges.

In the following sections, I first introduce the participants in more depth, then describe how participants leveraged their prior experiences, both from their home communities and from other teaching experiences, during the professional development meetings. I will then examine the boundary crossing episodes based on those shared prior experiences that occurred during the professional development meetings, including how the boundary crossing episodes did or did not support instructor learning about teaching practices. Finally, I will share how instructors built on those boundary crossings to inform their teaching practices during summer camps.

Participant Biographies and Home Communities

In this section of the findings, I will share more about each of the individual participants, including their educational background, prior teaching experiences, current profession, and their motivation or goals for participating in these professional development meetings. These factors, and other salient details of participants' backgrounds shared here, were used to determine each participant's primary home community. Primary data sources for these biographies were the individual interviews (primarily the pre-interview) and the professional development meetings. Given the embedded case study methodology of this research, participant backgrounds are important in understanding how and possibly why instructors interacted with other participants in the ways that they did. Each one of these people is a unique individual whose contribution to the shared learning environment of the professional development meetings and their potential learning through their participation is affected by their prior and concurrent experiences in their other communities. I begin with George, because he has the most experience with informal STEM education, followed by Margaret, who is closely affiliated with George professionally. I then share Sarah's background, as the newest of the returning Science Discovery instructors. Background details about Chris and Alex are shared next, as both are new Science Discovery instructors who remained in the study through completion. Lastly, I will write about Nicolaus and Matthew, both of whom did not complete the study, but are still included in the findings because of their presence at some of the professional development meetings. These names are pseudonyms, chosen by the participants themselves in most cases. Additionally, I will share here a brief autobiography because, while I was the designer and facilitator of this series of professional development meetings, as well as being the primary investigator for this study, I was also a participant in these meetings and drew on my previous experiences alongside the

Science Discovery instructors to address mutual problems of practice. Thus, my interactions with the instructors were considered as part of the analysis and findings as well.

George. George was a very experienced informal science educator, having taught with Science Discovery for nearly 20 years. In addition to teaching year-round with this institution, George also tutored students in Mathematics, volunteered to teach Mathematics in local schools, and worked on a professional development program with a university professor training K-12 educators in computer science instruction. Before George began focusing on education-themed work, he was an engineer in the "nuclear navy" (Pre-Interview, March 7, 2017) and a computer scientist. His interest in being a part of this project stemmed from an acknowledgment that he wouldn't be able to teach forever. With so much of his curriculum and teaching methods stored in his head, he was looking for a way to pass on some of his knowledge and expertise. George held an undergraduate degree in Engineering and Master's degrees in Engineering and Computer Science. Based on this background, I identified two communities as being George's primary home communities: informal STEM educator for Science Discovery and the computer science professional development research team.

Margaret. Margaret was also a returning camp instructor for Science Discovery during this summer and, as an instructor who'd not been formally trained as a teach, was participating as a way to learn more about formal teaching practices. Margaret held a Master's Degree in Computer Science and, while retired from her career as a computer scientist, continued to work at the intersection of computer science and education, being involved in the same professional development project for K-12 teachers as George, but focusing more on curriculum-writing than actively participating in teacher training seminars. Margaret enjoyed teaching as a way to support children, girls in particular, in learning about coding and was particularly interested in supporting

her campers in designing aesthetic and affective aspects of computer science. Because Margaret typically only taught for Science Discovery in the summers, I considered the computer science professional development research team to be her primary home community.

Sarah. As this group was engaged in professional development meetings, Sarah was completing her Master's Thesis in Geology and had been accepted into the PhD program in Geology at the same university for Fall 2017. While Sarah had an extensive background teaching in a wide variety of other informal contexts (e.g. ski instructor, swim instructor, tutoring, recess activity coordinator), the summer of this project was only her second year working for this institution. Prior to her first year as an instructor, she was recruited via an email originally sent to teachers in the local school district that was forwarded to her Geology department. Sarah really loved teaching geology to children and was torn between following a career in science or a career in education. Working as a summer camp instructor allowed her to do both. She was interested in participating in this project because she wanted "some understanding of child development, and understanding different levels of kids' development" as well as "a better idea of how to do my intro lectures in a way that's more engaging and not me pontificating at kids" (Pre-Interview, March 14, 2017). However, despite her interest in teaching, that role is secondary to her role as a geology graduate student, which I considered her home community.

Chris. Chris was a new instructor at Science Discovery for this summer. At the time of the study, he was a recent graduate with a BA in Communications and a minor in Education from a local university. During the 2016-17 school year, Chris had been primarily employed locally as a preschool teacher. He was recruited as an instructor by a parent at the preschool who had connections to the summer camp program as well. Prior jobs, each of which had teaching components, were as a bicycle instructor and camp counselor (nature specialist). He expressed a

deep interest in the socio-emotional aspects of children's learning, focusing on issues such as helping kids make friends, connecting with nature and feeling comfortable in the outdoors, and working through frustration. Chris described that his primary goal in leading camps was to help kids have fun with science. He based his curriculum decisions on what felt fun to him, drawing on his personal experiences doing various hobbies such as biking and rock climbing as well as his professional experiences teaching in other summer camps and as a preschool teacher. While he had some prior experiences teaching, he identified himself as a new teacher, with little teaching experience. This new teacher status was one he mentioned repeatedly during interviews, saying things like "I'm a bit younger than [Science Discovery's] general cast, so I think there's definitely that less experience factor" (Pre-Interview, March 23, 2017). He was uncomfortable with writing curriculum, but was very comfortable with planning out camp activities and adapting existing curriculum to his purposes. Chris described his teaching style as interactive (not lecture style), conversational, and informal. He wanted his campers to be excited about being in science camps and wanted to help them feel confident in exploring nature further once camp was over. He was less comfortable planning and teaching his building and transportation classes than he was teaching his nature field camp, but was equally enthusiastic about all of his classes. Given that his full-time job, even while teaching summer camps, was as a preschool teacher, I've identified that as his home community.

Alex. Alex was a secondary Mathematics teacher, teaching in a local middle school during the course of the professional development meetings. I identified this as her home community. She held a Bachelors of Science in Mathematics with an Education emphasis and a minor in English. She had been a Noyce Scholar for six years, participating in teacher professional development with them, and was participating in this project because "I'm always

interested in joining professional development because you never know what you're going to get out of it. And also, I know that a lot of the teachers here are not teachers in the real world, so I thought I could also lend my hand there." (Pre-Interview, March 13, 2017). This was Alex's first summer teaching at Science Discovery, having been recruited through an email sent to her school principal by Brian Jernigan, but she had prior experience teaching both in summer camps at other venues and as coordinator for an after-school club. One of her stated professional goals was "getting more girls specifically involved in STEM" (Pre-Interview, March 13, 2017) and she felt that teaching in informal contexts like summer camps and after-school clubs could help her reach that goal.

Nicolaus. Nicolaus was a newly credentialed secondary science teacher, specializing in secondary Physics. I identified this as his home community. He had previous experience teaching overseas in both formal and informal contexts, but this was his first summer working for Science Discovery. Nicolaus wanted to be a part of this community as a way of extending his teacher education for the specific context of teaching in summer camps. He participated in the project through the completion of the professional development meetings but did not end up teaching a summer camp during the focus month of July and was, therefore, excluded from continuing in the study.

Matthew. Matthew was a credentialed secondary Social Studies teacher who also taught a Maker class at his middle school. I identified this as his home community. He had an undergraduate degree in Communications and had briefly worked in radio before returning to school for a degree in Education with a History minor, specializing in Urban Education. He had previous Social Studies and History teaching experiences in both high school and middle school classrooms, but had a latent interest in Engineering and felt that teaching for Science Discovery

would allow him to build on that interest. He wanted to be a part of this project to help him understand what STEM classes typically look like, as a way of further developing his new Maker class at the school in which he worked. He described it as "immersing himself in the work of this new STEM field" (Pre-Interview, March 16, 2017). Matthew participated in the study through the first professional development meeting after which point he withdrew from the study due to scheduling conflicts.

Becky (Facilitator). At the time of this project, I was a doctoral candidate in Curriculum & Instruction, Science Education. During my graduate school career, I had worked on research projects involving professional learning communities focused on formative assessment practices for secondary science teachers (both online and in face-to-face contexts), pre-service elementary teachers working with 4th and 5th grade public school children across formal and informal contexts, and studying citizen scientist volunteers in a genetics lab embedded in a large natural history museum. Additionally, I was the primary instructor for my university's elementary science methods class for two semesters. Prior to my doctoral studies, I had earned my undergraduate degree in Molecular, Cellular, and Developmental Biology with a minor in Education, and a California teaching credential in Single Subject Biology and General Science. I taught elementary science for 14 years both in elementary schools and in after-school classes and summer camps for a children's science center in California. At the time of this study, I identified my graduate school program as my primary home community.

Leveraging Prior Personal Experiences in Professional Development Meetings

In this first section of findings, I will describe how participants leveraged and shared their prior or concurrent experiences from other communities in the professional development

meetings, looking from both a holistic group view and then focusing on individuals' patterns of participation.

Shared prior experiences: Group overview. Over the course of five professional development meetings, participants shared a total of 172 prior experiences during individual talk turns. This represents 12% of the total number of 1424 talk turns that occurred during all of the meetings. For the majority of the time, participants were not explicitly sharing their prior experiences when engaging in conversations. These incidences of sharing prior experiences were not evenly distributed over the course of the five meetings, however. Meetings one through four had between 25 and 33 shared prior experience talk turns, whereas Meeting 5 contained 53 such talk turns. Participants shared more of their prior experiences during the final meeting (a 47% - 62% increase) than they did in any of the prior four meetings. The most obvious reason for this occurrence is due to increasing familiarity and comfort with other participants. However, if that was the case, the data would likely show a steadily increasing number of shared prior experiences in each successive meeting. This was not the case however, as the number of shared prior experiences in Meeting 5 showed a distinct and dramatic increase. I hypothesize that the increased number of shared prior experiences in Meeting 5 is due to a combination of increased familiarity between participants and a substantively different meeting format in which participants were asked to attend to real-world emergent challenges to teaching summer camps at this institution. The Brainstorm activity that was the focus of Meeting 5 provided more opportunity for participants to talk and share, and pushed participants to think beyond more common challenges discussed in previous meetings. Using Star's (1988) terminology, the Brainstorm activity served as a boundary crossing space in which participants were asked to solve an ill-defined problem for which any proposed solutions were the result of a relatively high

level of uncertainty. This activity will be described more in depth during Vignette One, later in this chapter. Activities such as this, in which participants utilize different perspectives to come to an understanding or solution can be thought of as a boundary space.

For example, during this Brainstorm activity that was the focus of Meeting 5, when the group was discussing the challenges that arise when campers miss or are very late to the first day of camp, George shared a cumulative summary of his prior experiences around this challenge, from his years of teaching in previous summers of camp at this institution. This shared prior experience by George preceded a question he posed to the group about what to do in these situations. This was a specific problem that had happened to him multiple times over the years and to which he had no immediate solution:

> It's not that often, but at least, over the summer, there will be one or two classes where somebody comes in late and I don't mean late like they came in an hour late, I mean they miss the whole first day. Sometimes a parent will call me and sometimes I've had the luxury of the parent calling me or letting me know or the staff letting me know that it's going to happen. (George, Meeting 5, May 24, 2017)

This shared prior experience excerpt is part of a boundary crossing episode that spanned 29 talk turns, and included both George and Nicolaus sharing prior experiences a combined total of eight times, and in which four of the seven participants present contributed to the conversation. This represents a typical pattern of shared prior experiences, which will be further described in a later section.

As Figure 2 below shows, participants shared more prior experiences during the Brainstorm activity in Meeting 5, with 46 shared prior experiences, than in any other single professional development activity. Think & Shares, Video Observation & Discussions, and

Dissecting Lesson Plans were also professional development activities when participants clearly drew on their prior experiences outside of this group to discuss activities. While participants did share prior experiences during moments of informal chatting, introductions, icebreakers, and meeting wrap-ups, those activities resulted in far fewer instances, despite my prompting of participants to share those types of experiences during such activities, which I'd designed specifically to allow participants to get to know each other.

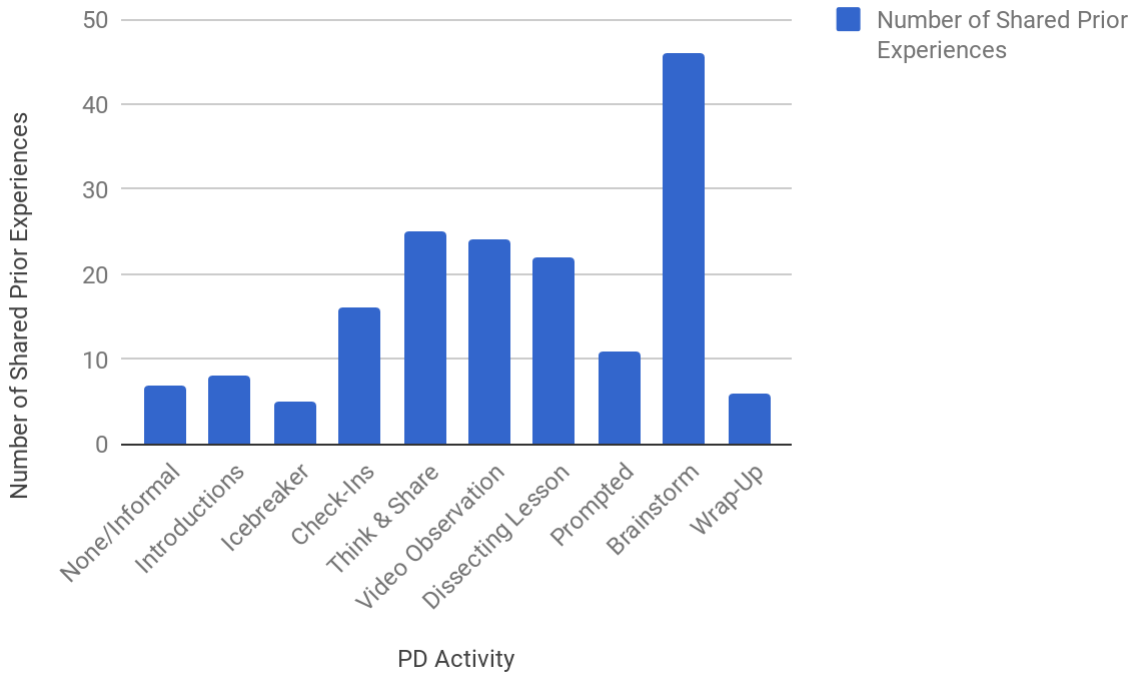

Figure 2. Shared Prior Experiences by Professional Development Activity

Shared prior experiences: Individual participants. When looking at sharing of prior experiences from a different perspective, that of the individual participant rather than as a whole group, patterns of participation emerge that become a theme throughout the meetings and the project as a whole. As the facilitator/researcher, I frequently acted as an intentional broker, sharing experiences across communities as a way to bring different perspectives into the

discussion. As an experienced former summer camp instructor and summer camp administrator, I used experiences from those contexts during the meetings. However, I also shared experiences as a university teacher preparation instructor and as a professional development facilitator in conversation. Figure 3 shows that I shared a prior experience more than 40 times over the course of the five professional development meetings.

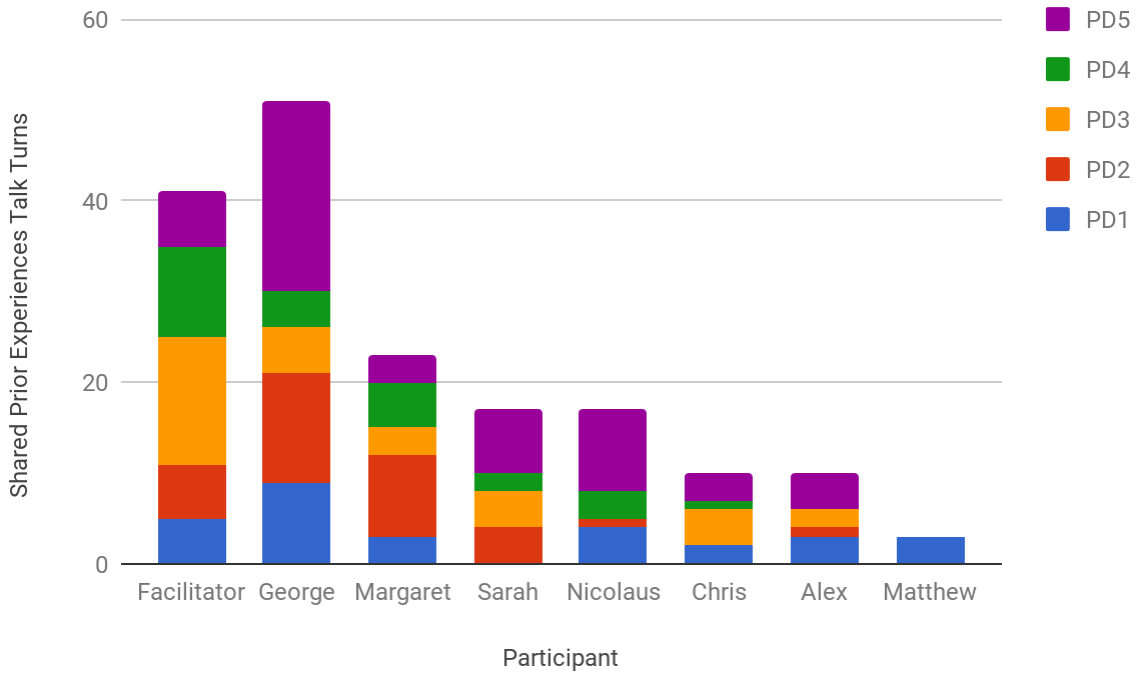

Figure 3. Shared Prior Experiences by Instructor

Given my intentionality as a broker in this context, I expected that I would have the most shared experiences out of all the participants. However, George shared more prior experiences than any of the participants, including myself, with 51 shared prior experiences; almost half of those shared experiences (N=21) occurred in the final meeting of the series. Of the total prior experiences he shared, George referenced 33 prior experiences as an instructor in this institution, while 20 talk turns referenced experiences in other communities he is a part of, including his volunteer work in local schools, experiences as a parent, and his work in an ongoing research

project around K-12 teacher professional development in computer science topics (note that some prior experience talk turns included references to multiple communities). This pattern of explicitly referenced personal experiences was indicative of George's collaborative teaching and learning style, as will be supported in further sections. Even as an experienced informal instructor, George actively searched for new instructional strategies for his camps and classes, despite being very confident in his abilities as a teacher.

By contrast, Margaret, the only other instructor participant who attended all five professional development meetings, frequently mentioned her lack of formal teacher training and preferred to listen rather than talk during the meetings. This is reflected in the smaller amount of times she shared her own prior experiences, with just over 20 instances. As another participant who had previously taught summer camp at this institution, she shared her experiences from those camps in 18 instances, with six other experiences shared from her work as a computer scientist, parent, and member of the same research team on which George worked. Sarah and Nicolaus both shared prior experiences 17 times and attended four out of the five meetings, although they were absent for different ones. However, with Nicolaus being a first-time instructor at this institution, this meant that all of his shared experiences were drawn from his fledgling career as a secondary physics teacher or from prior camp instructor experiences at other institutions, while Sarah's shared experiences were drawn from both her experiences as a Science Discovery instructor (N=12) and from her home community as a Geology graduate student (N=5). Chris and Alex, although also present for four out of five meetings, shared their prior experiences 10 times each. All of their shared experiences were drawn from communities outside the context of this institution, as both were first-time instructors during this summer.

Alex and Matthew both had mitigating circumstances around their participation that likely artificially reduced their opportunities to share prior experiences. The online context of these professional development meetings meant that issues with internet connections and video/audio quality, as Alex experienced, made it very challenging to hear her contributions. As a result, she tended to keep her computer on mute and participated in conversations through the chat function of Google Hangouts, which would be read out loud to all the participants by the facilitator. Matthew was unable to continue in the project after the first meeting and withdrew from the study. However, the number of times he shared prior experiences during the first meeting (N=3) was similar to all other attendees, with the exception of George, who shared nine times in that first meeting.

Shared prior experiences: Teaching experiences. My original conjecture for this study was that participants would draw on experiences from their home communities during their participation in these joint professional development meetings. I found that, in fact, they more frequently drew on their prior or concurrent teaching experiences, whether those experiences were in their home community, during previous summers teaching for Science Discovery, or in other teaching contexts.

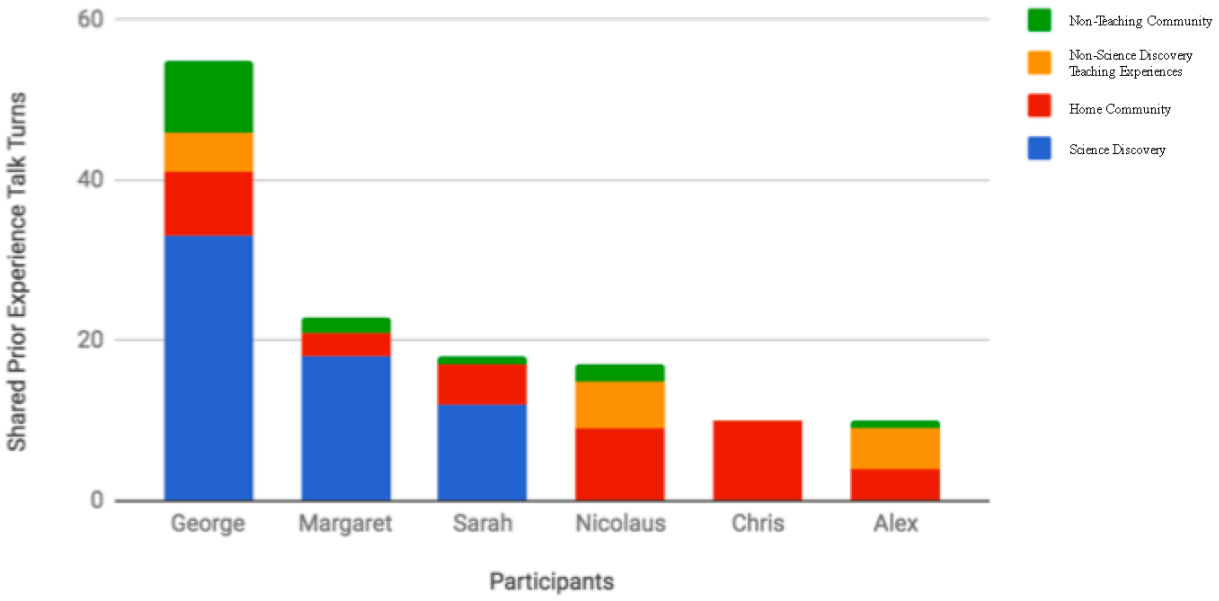

Figure 4. Community Source of Shared Prior Experiences by Participant

Returning Science Discovery Instructors. Instructors who had previously taught at Science Discovery (George, Margaret, and Sarah) were more likely to share experiences from teaching for Science Discovery than from other teaching experiences they may have had (see Figure 4). While true that, for all three of these instructors, the majority of their teaching experiences had been with Science Discovery, they all also had experiences teaching either adults or children in other contexts, yet they shared those experiences less frequently. Sarah, for example, was a graduate student in Geology during the course of these meetings, but had taught both for Science Discovery and in numerous other contexts (children's swim and ski lessons, tutoring, after-school programs). However, while she shared prior experiences a total of 17 times during the PD meetings, 11 of those times referenced her experiences teaching for this program in prior summers, such as in this excerpt:

> I actually had one of those [teaching assistants] in one of my classes last year and they were really really helpful. I just had one student who needed help focusing during group time and so she was able to sit with him and find special solutions. We ended up finding silly putty for him to just have in his hands and he would like sit in her lap during group activities and stuff because he responded really well to that. So, [the extra teaching assistants] are also really helpful, which I really liked last year. (Sarah, Meeting 5, May 24, 2017)

Here Sarah is contributing to a discussion on how to work with children who have behavioral challenges such as autism, in the camp environment. As part of the brainstorm activity in this meeting, Margaret had asked the group members how they would suggest handling this occasionally disruptive type of child. Sarah shared the above excerpted experience, following contributions by other group members. One of those comments included Margaret passing along the suggestion of the camp program coordinator that she should let him know if she would like one of the extra teaching assistants to come to her camp and help out. In this instance, Sarah's sharing of her prior experience at this institution, explaining the existing infrastructure designed to support instructors, reified the program director's offer of additional assistance and helped reduce Margaret's level of concern.

Furthermore, of Sarah's remaining six shared prior experiences, one was a reference to her education in a non-traditional elementary school, while the other five were related to being a Geologist. In three of her shared prior experiences referencing her geology home community, Sarah shared updates on the progress of her Master's thesis, which means that she only explicitly referenced her home community in the context of teaching twice:

> ...so the class I am most nervous about this summer is a high school course on all lab visits...A couple of the labs I work in [at the university] are doing lab tours for us. I know from experience that sometimes lab visits can be boring depending on how they are done and so when I set these up, I am really trying to shape how they are done. For example, in my lab I am getting a few kinds of coffee from different regions and then we are going to look at the isotopes of coffee from different regions… (Sarah, Meeting 5, May 24, 2017)

Sarah is using her resources and experiences as a geology graduate student to make her campers experiences as interactive and engaging as possible. The other instance in which Sarah explicitly references her home community is during PD Meeting 4, when she responded to a Think & Share activity asking why teaching science was important to her. One of her responses is that she teaches science because

> ...having gone to an inner-city school and taking classes with a bunch of students who don't look like me and then getting into upper level science and going to conferences and only seeing people who look like me has been kind of a weird and startling experience. (Sarah, Meeting 4, May 9, 2017)

Sarah is referring to her identity as a White person who attended K-12 schools where her classmates were mostly students of color, and then the prevalence of White people in her home community of Geologists. Teaching gave Sarah the opportunity to support students "who aren't traditionally represented in STEM and particularly Earth Science" (Meeting 4, May 9, 2017). Sarah's relative lack of references to her home community during the professional development meetings is notable, given that her home community as a geology graduate student had the least overlap between home community and teaching in informal environments of any of the participants in the study.

George and Margaret, both of whom were returning Science Discovery instructors, also drew primarily on their prior experiences teaching in that context, with 78% and 60% (respectively) of their prior experiences being from that community. This is particularly interesting in George's case, given his extensive teaching experiences in other contexts (e.g., volunteer math instructor in local schools, tutoring, and teaching K-12 teachers in professional developments). George and Margaret have many professional overlaps in that both are previous Science Discovery instructors, both work on a research project around professional development for K-12 teachers in computer science topics, both had former careers in similar STEM fields, and both are parents (the only ones in this group, aside from the facilitator). Given their similarities, I focused here on examples of George's prior experiences with regards to both his work as a Science Discovery instructor and in other teaching environments.

George, given his varied and extensive professional experiences, drew on multiple communities during discussions, occasionally doing so within a single long talk turn. As previously stated, most of his shared prior experiences were from his extensive career as a Science Discovery instructor, such as the talk turn shared below when he is responding to a Think & Share prompt asking, "What does a good summer camp learning space look like?" (Becky/Facilitator, Meeting 2). George's shared prior experience came on the heels of Margaret's shared prior experience about when to take breaks within a 3-hour or 6-hour camp day:

> Margaret: I also learned to stop the class after an hour and ask for show of hands about who was ready for snack time, because I discovered about half my students don't eat breakfast, and they're really jazzed at the beginning and then they just start sliding down feeling grumpier and grumpier and hungrier and

hungrier. Usually now I have snack after classes run for about an hour, or an hour and a quarter, and then they'll come back and work quite happily for a couple more hours. But that's another piece of the comfort thing: are they hungry?

George: And that's especially true in the morning. In the afternoon it's probably less so. Although I've had students skip lunch, which is not a smart thing, but you don't know that until later on. But I think it's also important when you're in an inside [camp] - and for people [in an outdoors-based camp], you're already doing stuff- but you have to force them to get up and go outside. Because when they're engaged, they're willing to sit there for 3 hours. And that's unhealthy. And they will resist getting up. "I'm right in the middle—nope, we're all going outside"...I'm glad they're engaged, but it's not healthy just to sit here for 3 hours. (Meeting 1, March 31, 2017)

These two talk turns are the final ones in a 30-talk turn boundary crossing episode centered around making sure students are comfortable and safe in the camp environment. This boundary crossing episode and the talk turns shared above (which are two of seven shared prior experiences in this boundary crossing episode) are notable for three reasons: first, this boundary crossing episode encompasses the first conversation around teaching practices in the initial meeting of the professional development series; secondly, this conversation is centered around camper safety and comfort which was one of the high-frequency Tracers; and third, because these shared prior experiences were both typical of Margaret and George, and set the tone for future shared prior experiences. In particular, George's acknowledgement that the classroom space for his and Margaret's computer-based camps were very different than those of Chris and

Sarah, for instance, who both taught field camps, or even those of the other instructors who, while they were based in classrooms, had camps with more physical activity built into the curriculum. Even with these differences, by sharing these experiences of children needing to eat and be outside, George not only conveyed the importance of building in these considerations into the camp schedule, but he worked in this boundary space trying to reconcile differences between the different camp environments. While on the surface, these might not appear to be critical topics, the importance of attending to such matters of guests' personal comfort and safety is recognized by both the museum field (Rand, 2001) and by experts in out-of-school time programs as being a key attribute to success (NRC, 2015).

While most of Margaret and George's shared prior experiences were centered on their prior summers teaching camp for Science Discovery, they did occasionally also share prior experiences from their home community with the university research team and from their experiences as professional computer scientists. George, for instance, made his campers work in pairs or would encourage them to use their peers as resources before asking him a question, claiming that professional computer scientists did not work in isolation, particularly in current work settings (Meeting 2, April 17, 2017). Margaret shared her feelings of isolation as a female computer scientist in a male-dominated field when she talked about why she thought teaching and learning STEM was important to her (Meeting 4, May 9, 2017). For both of these instructors, their shared prior experiences demonstrated their navigation between their home and other professional communities and this community centered around teaching summer camps.

New Science Discovery Instructors. For those participants who were new to Science Discovery this summer (Chris, Alex, Nicolaus, and Matthew), they also drew primarily on prior teaching experiences, rather than on other communities they were a part of. For all of the new

Science Discovery instructors, their home communities were also teaching communities, albeit ones set in different contexts. This overlap of home community and teaching community contexts makes the sharing of prior experiences from those communities a logical resource to have drawn on. Chris, for example, only shares prior experiences based on his job as a preschool teacher, as in the excerpt below, where he is responding to a prompt about why the instructors think teaching STEM is important:

> We're getting people excited about science and you're also making it clear that guys, gals, and non-binary pals can be in science. At the preschool, we've got so may Elsa's who are guys. I don't know if you guys are familiar with that. There's this Disney movie about a princess, it's kind of like Cinderella. But yeah, one-third of the guys [are] wearing Elsa dresses. Who gives a [s--t]? Still having fun and doing everything. You're breaking down these barriers, and also traditionally, there aren't a lot of men in elementary teaching positions. So me just being there having fun and putting on a show every day, there's got to be at least one person who's like "Oh wow, I could do this. Cool." Take the science out of it and it's like "I can be a teacher. Awesome!" (Chris, Meeting 4, May 9, 2017)

Not only does this excerpt show how Chris shared from his home community as a preschool teacher, it also highlights one of his main instructional goals to support his students' socio-emotional growth. This boundary crossing from his home community to this professional learning community will be discussed further, in Vignette Three.

Whereas Chris shared prior experiences exclusively from his job as a preschool teacher, Alex shared prior experiences from both her home community job as a middle school mathematics teacher and from her work as an after-school STEM club leader, among others. Her

10 shared prior experience talk turns are evenly split between her home community and her other teaching experiences, with one instance of a non-teaching shared prior experience. One such example was during Meeting 3 when, during Check-Ins, Alex shared that she and some students in her after-school science club "went to the local elementary school and we got to do science experiments with them and it was really fun!" (Meeting 3, April 26, 2017). Given that the prompt for the Check-in was very open-ended, I had asked them to share any events coming up that might be interesting to the group or what was going on with them, it was interesting that Alex chose to share an event that closely aligned with activities this group might do, rather than an event from her mathematics classroom.

Shared prior experiences: Summary. When looking at only instances of shared prior experiences, participants most strongly drew on experiences that were more closely aligned with the context under discussion in these group meetings, such as experiences teaching in this or other informal settings. However, when appropriate and relevant to the topic under discussion, participants did draw on other experiences both as a way to support a specific teaching practice and as reflective practice on their own teaching. Design of the professional development meetings reflected differing levels of participation, with a distinct increase in shared prior experiences that occurred during the final meeting, after participants were acquainted and relatively comfortable with each other and the online setting, and during which the focus of the conversation was embedded in emergent problems of practices that had not been addressed or solved in previous meetings and that were often ill-defined problems of practice.

Boundary Crossing During the Professional Development Meetings

In this section of the findings, I will first share exemplars of intentional facilitation strategies I used to encourage the sharing of prior experiences during the professional meetings.

Then I give an overview of all boundary crossing episodes that occurred in the professional development meetings, including three vignettes describing the context around a boundary crossing episode and evidence of instructor learning as change in participation or practice that occurred. The first vignette describes a boundary crossing episode in which four participants discuss a teaching challenge of one instructor (Sarah), and then her subsequent actions traced back to that boundary crossing episode. The second vignette describes a new teaching practice for Science Discovery instructors that resulted from the boundary crossing episode that will be described in Vignette One, and how that teaching practice became a part of the representational infrastructure within Science Discovery through multiple enactments (George, Alex, and Margaret). The third vignette describes a boundary crossing involving Chris sharing his instructional goals around helping campers make new friends, and how sharing this instructional goal in the context of his experiences teaching preschool informed the teaching practices of multiple other participants in this professional learning community. Finally, I will share a counterexample of a boundary crossing episode which had no discernible effect on informing instructors' teaching practices.

Facilitation of Professional Learning Community. During the course of the professional development meetings, while acting as facilitator, participant, and researcher, my actions and choices guided the conversation. As facilitator and researcher, I intentionally modeled verbal contributions to prompt sharing of concurrent or prior experiences from other communities in which instructors participated. I did so by sharing my own prior experiences as a summer STEM camp instructor and my own other communities. In the excerpt below, from Meeting 1, during a discussion about characteristics of good summer STEM camps, Nicolaus proposed that camp activities that involved challenges are very effective in keeping campers

engaged. He goes on to describe an activity about simulating the colonization of the planet Mars. I had used a similar activity many times during my years of designing and teaching a physics based summer camp and briefly shared that with the group, saying:

> You reminded me of the time when I once had kids build cars to drive over an entire tub of oobleck...it's [a mixture] of cornstarch and water...It just reminded me of the time when I had kids do [a] Mars rover thing, trying to design it, giving [them] a challenge. My point was that's something I think we see a lot in informal [learning] environments. (Becky/Facilitator, Meeting 1, March 31, 2017)

I often shared prior experiences from my years as a summer STEM camp instructor during conversations with participants, partially to situate the abstract concepts we were discussing into real-life contexts while acting in my facilitator role, but more frequently as a way to align my projected identity with that of the participants. I wanted participants to see me as one of them, as someone who understood the challenges they were facing as instructors from the emic (insider) perspective, and sharing my own experiences as a summer camp instructor served that purpose of building rapport.

One example of an instance in which I explicitly shared a prior experience as a way to validate the teaching practices of an instructor was during Meeting 2, when the group was "dissecting lesson plans". Margaret talked about how she liked to "flag the places where I know students will have trouble...and so actually what I've been doing, which may seem incredibly stupid to anybody who looks at my notes, is actually script out what I want to say…" This teaching practice of scripting out or making a list of talking points resonated with how I wrote lesson plans as well, and I shared my own experience as a way of validating Margaret's practice.

> I'm going to go ahead and say I don't think that's stupid. I used to call them spiels and they were [written into] my lesson plans. [It was] how I was thinking I would say it [to students], not that I would read it like a script, but it was my train of thought [for] how I was going to explain it. (Becky/Facilitator, Meeting 2, April 17, 2017)

After this talk turn, Margaret went on to add more detail about her lesson plan writing process, followed by George sharing his own process for how to notate talking points. These talk turns in which Margaret and George elaborate on their teaching practices demonstrated how my intentional sharing of a related prior experience that positioned me as an experienced and knowledgeable peer encouraged similar contributions from participants.

Other instances in which I shared my own prior experiences included brokering talk moves, when I drew on my participation in multiple communities during a conversation to solve an emergent problem of practice. In instances like the one below, I tried to build on a participant's contribution by sharing my own prior experiences, as justification for a potential solution. During Meeting 4's Check-In discussion, Margaret told the group about feedback she'd received from the summer camp administrator regarding designing a productive activity for campers to engage in while waiting for all the campers to arrive each day. Chris asked, "Aren't there little computer games they can kind of just noodle around on that are instructive, but…?" I built on Chris' comment, as well as an intervening talk turn by Margaret, when I said:

> I like the idea Chris had of just having exploring time, and I wonder…yes kids can play [video games] at home, but at the same time, I bet you know and other [campers] know games that they wouldn't know at home. I'm literally playing off my experience as a parent [here]. I don't know video games at all, we don't have video game systems in my house. But my daughter – my 3rd grader – is obsessed with coding right now, and so she

> talks to other kids and hears about games and she comes home playing them. But I wonder if you could parlay that into you picking a specific game that's online and available for [them] as they come in. Sort of like an introduction – [you] want them to play this because the thing that they're doing in this game is going to then relate to something that [they're] doing in camp that day. Kind of like a focused playing time [that] would serve a purpose. (Becky/Facilitator, Meeting 4, May 9, 2017)

In this talk turn, I share an experience based on my personal life, as a parent of child in the same age bracket as the campers being discussed here, as well as my experience as a summer STEM camp instructor who had designed many productive introduction activities, to propose a justification. In doing so, I build a connection between instructor's talk turns and bridge multiple communities. The importance of the ways in which I facilitated these meetings will be further discussed in the next section, where I describe the shared prior experiences as they are embedded in the boundary crossing episodes.

Boundary crossing episodes: Overview. There were 67 boundary crossing episodes sampled around the 172 shared prior experiences, with an range of 1 to 16 shared prior experiences per boundary crossing episode, and an average (mean) of 2.6. The boundary crossing episodes together encompassed nearly 60% of talk turns across all five professional development meetings. As with the data analyses around the shared prior experiences, the conversation that occurred during Meeting 5 included a higher number of talk turns (78%) sampled in boundary crossing episodes than conversation in any of the other four meetings, as number of talk turns included in the boundary crossing episodes averaged 54%. This higher amount of conversation around shared prior experiences in the final meeting supports the claim made in the previous section that engaging instructors in discussions around emergent and situated problems of

practice, at a point in the sequence of meetings when instructors are familiar with each other, could provide a productive learning environment for instructors.

Turning now to a more qualitative analysis of the data, 50 of the original 67 boundary crossing episodes were identified as discussions involving shared prior experiences around problems of practice related to teaching. This large proportion of boundary crossing episodes related to teaching (75%) indicates that the design of this type of instructor professional development can be a productive site of opportunities for learning based on participants varied professional communities. I further analyzed the 50 teaching-related boundary crossing episodes for patterns of topics around teaching. These analyses showed that most of the boundary crossings, nearly half, occurred around teaching practices that instructors used during camp instructional time (N=23). A smaller but still significant number of boundary crossing episodes were centered around the logistical challenges of teaching summer camps (N=17). Instances relating to topics of socio-emotional support for students (N=4) and instructors reflections on and motivations for teaching STEM (N=6) represented a much smaller proportion of boundary crossing episode topic patterns. With the exception of Meeting 4, where the focus of the prompted discussion was instructors' personal motivation and reasoning for teaching STEM, the professional development meetings included boundary crossing episodes that were a mix of primarily logistical topics and teaching practices.

The boundary crossing episodes shared in the findings as vignettes were selected because of strong evidence the interaction that occurred during the conversations resulted in a boundary space and that the problems of practice addressed in the boundary crossings informed instructors' teaching in their summer camps. In the case of the first boundary crossing episode shared (Vignette One), the main topic was one of teaching practice, specifically how to get and

keep students engaged during camp activities, a topic that underlies many curriculum and teaching design decisions, particularly in informal learning spaces where attendance isn't compulsory. This first vignette is followed by Vignette Two, where I describe a change in teaching practice that results from the boundary crossing episode described in Vignette One, where three of the instructors engage in a new-to-them teaching practice of switching campers to allow each group an opportunity to share their work with others. The second boundary crossing episode (Vignette Three) related to the socio-emotional support of students. I chose to share this boundary crossing episode specifically because this was not a frequent topic and was championed largely by one participant, but was cited as productive by other participants in follow-up interviews.

Vignette One: Sarah and The Boring Lab Tour Problem of Practice. It was late May, mid-way through the fifth and final meeting of this online community of informal STEM instructors. The first session of summer camp started in just six days, and while not all of the instructors are scheduled to teach that first week, the pressure to be ready for camps was apparent. Given the impending start of camps, the focus of the meeting was to brainstorm solutions to lingering or emerging challenges and concerns of the instructors. Prior to the meeting, Instructors had been asked to post questions and concerns about upcoming summer camp instruction in a shared Google Drive document. By this point in the project, despite the constraints of the online meeting platform, instructors were fairly familiar with each other, having participated together in three or more online meetings, and felt comfortable engaging in discussions around problems of practice, as evidenced by the increased amount of conversation centered around problems of practice, even though most of them had not met in person (with the exception of Margaret and George).

The meeting started with the type of off-topic chatter that is characteristic of so many professional gatherings. Once everyone had logged on to the Google Hangout, I began by asking people to share when during the summer they would be teaching camps, an activity that I referred to as Check-Ins and for which I typically provided a prompt. I wanted the instructors to know when other members of our group were teaching, in case they had the opportunity to see each other. Later I would further support this goal by posting who was teaching, on the Sunday before the camp week started, in our Google + group.

After everyone had a chance to respond, I shifted the focus of the conversation to the shared document with the compiled "brainstorm, talk with the group about, or just share" (Facilitator, Meeting 5, May 24, 2017) notes and suggested that whoever wanted to speak first was free to do so. George was the first to speak, a typical occurrence, noticing as he looked at the shared document on his own computer, that several instructors had posted about how to manage children with autism or other learning challenges. Several more questions were addressed and discussed with the groups, many of which proved productive for instructors. Then, as we wrapped up a discussion based on a question from Nicolaus, George asked Sarah about a dilemma about which she had expressed concern regarding how to manage students who aren't on task during lab visits (Artifact, Meeting 5 Shared Notes, May 24, 2017). Sarah explained her concern further, part of which was shared in an earlier excerpt, but is presented here in its entirety:

> Sorry, I had my mic off and didn't realize it…So the class I am most nervous about this summer is a high school course on all lab visits and it's…like the hook line of the [camp] is how do we study past and present climate change through geochemistry. So we are going to [local government science organization] to go do a visit and go to the

> [large university research laboratory] laboratories. A couple of the labs I work in at [my university] are doing lab tours for us. I know from experiences that sometimes lab visits can be boring depending on how they are done and so when I set these up, I am like really trying to shape how they are done. For example, in my lab I am getting a few kinds of coffee from different regions and then we are going to look at the isotopes of the coffee and talk about how we can see the differences in the climate through the coffee itself, and [the campers] get to pack caffeine into these little tubes and blow it up and see the data at the end and we get to talk about it.
>
> I'm trying to devise activities for them too. But the ones like [local government science organization], where we are going to go in and we are going to visit their labs, I don't have a whole lot of control over what they are going to show us. I am a little worried that I am going to have eight very bored high schoolers and so I am trying to think of ways to keep them engaged and on point and not yelling at them and be like, "hey!" Because I don't want this to be like school. I don't want to be like a high school teacher for them. This is supposed to be cool and I'm hoping because they are high schoolers who are choosing to go to a science camp that they are engaged and they are into it. But even I get bored in some of these lab tours. So those are the things that I'm most nervous about for the summer. (Sarah, Meeting 5, May 24, 2017)

George's comment is the beginning of a 29-talk turn boundary crossing episode. Despite the length of this episode, one of the ten longest boundary crossing episodes out of 68, this episode included only two shared prior experiences. Instructors who participated verbally included Sarah, George, and Margaret, as well as myself. While the analyses of boundary crossing episodes focused on participants who spoke, the Tracing analysis of observations and interviews indicated

that verbal participation in a conversation was not always a necessary indicator for a boundary crossing episode to have informed teaching practices. So it is also important to note that Alex, Nicolaus, and Chris were present, but did not speak during this boundary crossing episode.

The first shared prior experience in this boundary crossing episode was by Sarah, during her explanation of the situation. Note that she doesn't ask the group a specific question to address, but rather shares her dilemma and then waits to hear the group's comments. The following diagram (see Figure 5) is a visual representation of the path of conversation for this boundary crossing episode. Talk turns coded as shared prior experiences are marked.

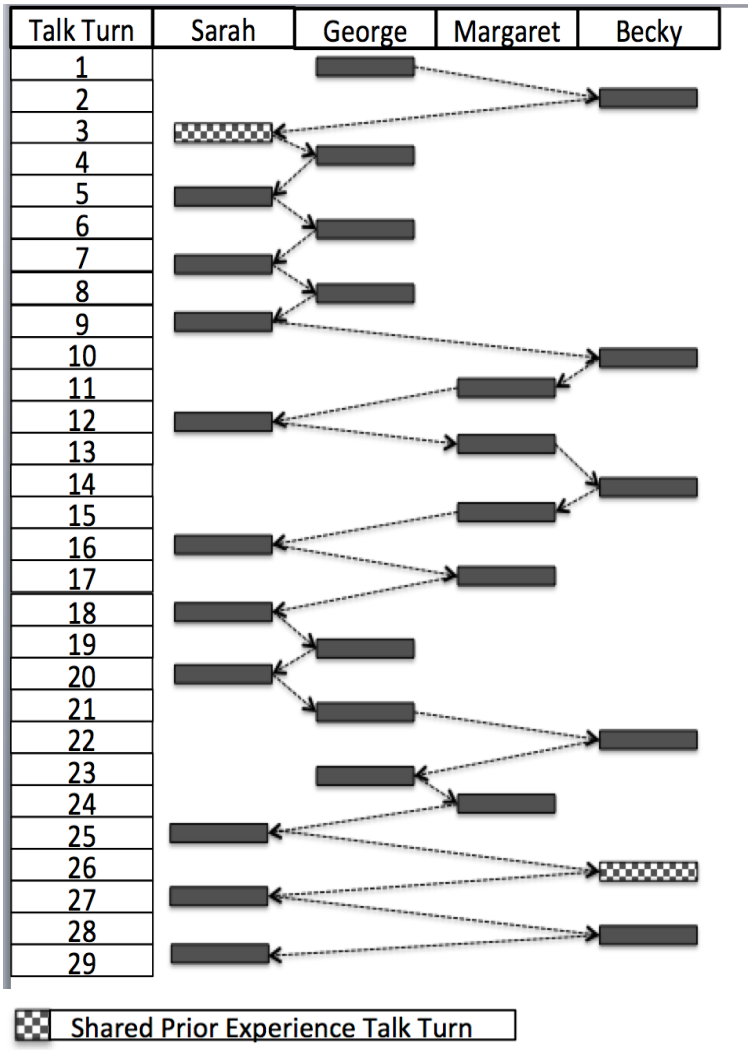

Figure 5. Boundary Crossing Episode Talk Turn Diagram (PD5_BC8)

George acknowledged the challenge Sarah faced and suggested building in some kind of hands-on activity, a suggestion to which Sarah responded positively. George asked if she had a classroom space assigned to her, and then followed up with a suggestion. I then made a suggestion about having campers think about questions ahead of time, before they go on a lab visit. My suggestion was expanded on by Margaret, who spoke for the first time in this meeting since her own question was posed to the group, which occurred nearly 40 minutes prior to this boundary crossing episode. It was this series of talk turns that lay the groundwork for two new teaching practices that would be successfully enacted by instructors during summer camps.

Line	Talk Turn	Speaker	Talk Turn
644 645 646 647	8	George	So is there is a way that you could structure it so that the lab tours are no more than 30 to 60 minutes and they come back and apply it somehow or do some kind of exercise where you… I mean I know I would be bored unless there is a topic I was interested in for 2-1/2 hours. That's a long time to just be talked to.
648	9	Sarah	Yeah
649 650 651 652 653	10	Becky (Facilitator)	At the risk of sounding too much like an elementary school teacher here. I wonder if you could do some really fun variation on like a K-W-L chart where you kind of prime them ahead of time. What do you want to know from this person, and what if they already kind of go in having questions that they've developed themselves then they might be kind of listening for that.
654 655 656 657	11	Margaret	Is there some way to reward people for asking good questions? Then they need to think about what they would ask in advance and pay attention enough to know when they would ask and sometimes something that can work, is have them create a poster to present this material to younger children.
658	12	Sarah	That would be interesting
659	13	Margaret	And then find some younger children. Science Discovery has oodles of them!
660	14	Becky (Facilitator)	Why yes, there are lots of young children around. That's interesting!
661 662 663 664 665 666 667	15	Margaret	Or get a place to hang their posters on the hallway, where people can hang out and look at them and encourage them to think about: what would you tell fifth graders? That's a great age group because they are just looking out at the world wondering, where is my spot in this complex place, outside of my family and my elementary school, where do I fit? If the challenge was to tell fifth graders what's really cool about the lab you visited. You could a take a pile of old magazines in there and some poster board and let them cut out letters or pictures.

668	16	Sarah	That would be cool!
669	17	Margaret	Well it appeals to people who are visual and who like doing stuff.
670 671	18	Sarah	Yeah. I have been struggling with like how to incorporate all kinds of learners. I really like that idea. That's a great idea Margaret.
672 673 674 675 676 677 678	19	George	If your class is the same time as mine, and you come back early, you can have your kids come in to my class and [Crosstalk: Sarah says Yeeeeaaaaah!] give my students a challenge to make a video game that kind of embodies whatever they just learned. Because the software we use is really science simulation software so they could make a simulation of climate issue or a weather issue or something like that, that could be one. Your kids would feel like pied pipers and my kids would look up to them as superheroes.
679	20	Sarah	That would be way cool.

(Meeting 5, May 24, 2017)

Following this excerpt, participants make a few more suggestions, including one which was about an end-of-camp activity that I'd designed when I was a summer STEM camp instructor. The group then moves on to discuss another question, signifying the end of this boundary crossing episode.

Sarah's high school geochem camp was a one-week session that occurred only once during the summer, in week six of ten total weeks of camp offerings. This was the first of roughly four weeks of camps I observed. During her post-interview, that took place just six days after Meeting 5 (and the same day that other instructors were starting to teach camps), Sarah said:

> ...I really liked the idea that we came up with in the last meeting, of like having them then create something at the end. And I think I'm going to give them a fair amount of flexibility on that. I'm going to be like "you can make a YouTube video if you have like an iPhone" because I have the video editing software for iPhones on my laptop. Or "you can make a game or you can make a poster, but it should be for middle schoolers", so like

> the one level younger than that [because] they are high schoolers. (Sarah, Post-Interview, May 30, 2017)

This excerpt supports the claim that conversations such as the one referenced here are boundary crossings that serve as productive sites of learning, resulting from discussion around ill-structured problems. Sarah took up and modified suggestions made during a conversation in a professional learning community meeting, in which multiple participants shared potential solutions to an emergent problem of practice that did not have a clear solution to any of the educators present. The activity Sarah ended up designing and enacting resulted from this group problem-solving discussion. Next I will share observations of the resulting camper activity designed and enacted by Sarah.

Shortly before camp observations were to start and almost a month after her post-interview, Sarah and I conversed by email and she suggested I come and see her end-of-camp activity for her high school camp. At that point, the actual structure of the activity had not yet been identified as a debate. When I arrived in her classroom space at the appointed time on a Friday morning, the high schoolers were working on preparing for their debate. They were sitting in groups scattered around the small room, most looking at laptops or smartphones as they researched evidence to support their positions. During this preparation time, Sarah moved from group to group, answering questions and asking the kids probing questions around the sources being cited in their arguments. This proved to be an interesting moment, because in pushing the kids to use valid and reliable sources, she explicitly referenced her experience as a geologist, describing the process for peer-reviewed research to her campers. While not the focus of this study, moments like these, where an instructor engages in boundary crossing activities with

campers, supports the claim that these types of boundary crossing activities can serve as sites of learning for both instructors and the young people with whom they work.

I observed the whole debate activity through to its conclusion, observing as campers demonstrated their engagement through their well-researched arguments, their questions about choosing legitimate sources for their data, and their enthusiasm to continue the debate once time was called. Sarah, in her follow-up interview, describes how she and her teaching assistant were astounded by the level of participation, given their having spent the week with these teenagers being mostly silent and unexpressive.

While this particular activity hadn't been directly suggested in the professional development meeting, Sarah attributes the conversation that happened in the boundary crossing episode described above (PD5_BC8) as her inspiration for designing an end-of-camp activity (Post-Interview, May 30, 2018). She wanted to think of an activity that required the high schoolers to build on experiences they had throughout the week in a way that meant that they were the ones doing the talking, presenting and sharing of ideas, rather than the instructor. The final activity, a debate, was a combination of a student-directed activity, built on knowledge the kids had gained during the lab visits and was a culmination activity. Both of these teaching practices, "student discovery" and "student talk", were important to instructors in this project, as identified by the high number of associated Tracers. All of these ideas were embedded in comments made during the boundary crossing episode, suggesting its' impact on Sarah's design of the debate activity. This claim is supported by her reflections shared during her interviews.

Boundary crossing episodes: Sites of learning about teaching practices. Vignette One demonstrates how learning can take place in a boundary space for one instructor. The instructor Sarah built on shared experiences from multiple communities to solve a problem within this

shared community. The communities being drawn from were, 1) the scientific community in the form of the labs Sarah's campers would be visiting, 2) Sarah's home community as a Geology graduate student, 3) George's home community as an experienced Science Discovery instructor, and 4) my own communities as an elementary science teacher educator and as a former summer camp instructor. Sarah found, in her fellow participants, people willing to try and negotiate through a common problem of practice, that of keeping children engaged, each drawing either explicitly or implicitly on their own prior experiences teaching, or from their home communities. George's contributions to the problem space, for instance, drew on his experiences listening to science lectures and even further, he offered Sarah the opportunity to combine the purposes of their camps in an intersecting activity. His offer to combine camps was built on ideas first put forth by Margaret and myself. What is clear from the beginning of this boundary crossing episode however, is that the problem being discussed is one that did not have a readily apparent solution. Even though several ideas were proposed by various participants, the final designed debate activity reflected not one single suggestion, but rather incorporated pieces of various ideas as Sarah worked towards a solution.

Boundary Crossings Informing Instructor's Teaching Practices

While Sarah didn't end up drawing explicitly on the suggestions made during the boundary crossing episode, other participants did. The idea to combine camps, proposed by George during the boundary crossing episode introduced in Vignette One, is an example of a boundary object. The boundary space of the PD meeting allowing participants to work across communities in this shared space to solve a problem, how to keep campers engaged. In Vignette Two, I will share how the new teaching practice of combining camps for the mutual benefit of both sets of campers became reified through multiple enactments during the summer camps.

Vignette Two: Switching Camps. About halfway through summer, on the Wednesday of Week 7, the summer camp administrative staff hosted an after-camp mid-summer staff appreciation party for all of the instructors and teaching assistants in the courtyard outside the Science Discovery building. There was pizza, soda, and ice cream provided for all to enjoy while chatting. In follow-up interviews, several instructors pointed out that this party was the first opportunity they had to meet and socialize with other instructors. This became apparent when I was chatting with Alex while eating some pizza, and she mentioned that her campers that week had progressed through the curriculum much faster than anticipated and she now had a hole in her schedule the next day with no planned activity. Remembering the conversation we'd had about Sarah's high school camp during Meeting 5, I suggested that she reach out to George, who was also at the party, and see if he wanted to collaborate with her, especially since they were teaching in adjacent classrooms. Alex, at first, didn't appear to be interested in the idea and we moved on to chatting about other topics. Later, while I was chatting with one of the program administrators, I saw Alex and George talking with each other. As I was getting ready to leave the party, Alex saw me and excitedly shared that she and George had arranged a time to swap campers the following day and that I should come and observe. Alex later told me that at the beginning of that week of camp, she'd had no idea that George was the instructor in the next classroom. Part of this was because George had a habit of only showing half of his face to the camera during the meetings, due to his computer setup at home, so that Alex had rarely had the chance to see his full face. But she'd seen him in the hallway outside their camp classrooms and had flagged him down to confirm his identity.

The following day, I observed as George had half of his campers (one from each pair of kids at a table) go with his teaching assistant over to Alex's classroom next door, while Alex did

the same in reverse. Both groups of campers were middle schoolers (11-13 years old) this week. In George's classroom, the campers were given the choice about who would go to the other classroom first and who would stay to share their video games. Once Alex's campers were settled in the classroom, each next to one of George's campers, George instructed his campers to tell the visitors about the game they had been designing and to let the visitors have a chance to play the game. I watched as the video game campers enthusiastically demonstrated their games to the Lego campers; lots of pointing at the computer screens and animated body movements. The visiting campers appeared to be listening intently, usually while looking at the computer screen, periodically pointing to something on the screen, and then looking at the video game camper to ask a question. After about 5 minutes, George encouraged his video game campers to show the visitors their coding and then to let them play the game themselves. This went on for another 15 minutes, until George told them it was time to switch. The laptop computers were closed and all of the kids lined up at the door.

I followed this group back to Alex's classroom, as the other half of the kids, who had been in Alex's room, filed into George's room. Once in Alex's classroom, she directed her Lego campers to show the visitors how to program their Lego Mindstorm robots to do something. For the most part, the campers stayed in the pairs they had been working with in the other room. Once again, there were ample signs of engagement in that both the Lego campers and the video game campers were pointing at the computer screens and at the robot, asking questions of each other, and getting the opportunity to try out new types of coding. The teaching assistant did tell one of the video game kids to put away his phone. The young man said he was bored because he had the same Lego Mindstorms at home. Alex suggested that he show something cool to her students then, but that the cell phone had to be put away. After 15 minutes, Alex had all the kids

line up together and let them know that the two classes would be combined for snack time. George had suggested this as a way of allowing the campers to continue conversations started in the classrooms.

After the kids left the classroom with the teaching assistants, Alex told me that she and George had done this switch in the morning as well. Although, while Alex's kids were there all day, George had been teaching a slightly younger group of late-elementary-aged campers during a half-day camp that morning. Both she and George separately told me that despite the age differences, the campers seemed to enjoy it and that the both age groups appreciated the opportunity to share their work. (Observation, July, 20, 2017).

In the weeks following, both Alex and George independently initiated more camp switches with other instructors from our professional learning community (Margaret and Alex switched) and with other Science Discovery instructors (George switched with an instructor teaching a class about Dash and Dot robots). Outside of the computer science-based classes, Chris also ended up coordinating a joint rocket launch session between a high school-aged Science Discovery class and his early elementary-aged physics campers.

Summary of Boundary Crossing Episodes Informing Instructor's Practices. This camp switching activity was a new teaching practice for Science Discovery instructors, an observation shared with me by both George and Jernigan, the summer camp program director. It was considered so successful by George and Alex, that they repeated the experience with other camps as well. In addition, George documented the switches by taking photos (a practice allowed by parent permission in Science Discovery programs) and emailed them to the Science Discovery administration. Jernigan was so enthusiastic about this new teaching practice that he came and videotaped one of the camp switches that I was observed. These repeated enactments

of a practice that emerged as a suggested solution to an ill-defined problem, during a conversation identified as a boundary crossing episode, resulted in a newly reified teaching practice for Science Discovery summer camps, supporting the conjecture that such boundary crossing episodes can inform instructors' teaching practices.

From Home Community to Informing Instructor's Teaching Practices

In the following vignette, I share a boundary crossing episode that was based not on a specific teaching practice, but rather on the socio-emotional support of young campers in particular, as championed by Chris. Whereas Vignettes One and Two were based on a boundary crossing episode in which multiple participants came together to solve a problem, drawing on various prior experiences and communities to do so, this boundary crossing episode involved a single instructor sharing his instructional goals for teaching a population of children that closely aligned with the ages of the children he taught in his home community as a preschool teacher. Chris's shared instructional goals around "making friends" was quite different from the instructional goals stated by other participants. However, while I was not able to capture any observations of this enacted practice, several instructors cited Chris as influencing their teaching pedagogies and the design and implementation of camp activities, describing them during their individual interviews. I see these self-reports as evidence of learning that resulted from ideas shared from a person with a different representational infrastructure, that occurred during the professional development meetings, constituting a boundary crossing episode.

Vignette Three: "making friends". We were about 25 minutes into the first meeting, each instructor participant taking turns answering the first of the Think & Share prompts about what a good summer camp space looks like, when Chris took the opportunity to share his philosophy about learning goals for the camp environment:

> I'll share something. So my camp might be a little bit different from the rest. [F]or a lot [my campers] it's their first time at camp. So while the goal is to teach, it also is to create opportunity for friendships to form. It's super important, 'cause if you're not having fun, making friends, [then] you feel all alone. Then you don't want to do stuff. So in that sense, a big part of it is making sure nobody is working alone, creating an opportunity to really engage with others and also engage with the instructor: myself. Have fun. Be safe. (Chris, Meeting 1, March 31, 2017).

Chris had said something very similar during his pre-interview, about the importance of helping his young campers make friends, so when he brought up this idea again following other instructors' comments about the set-up and comfort level of classroom spaces, I took note of it. About 20 minutes later, as the participant's contributions to this prompt decreased to the point of silence, I took advantage of the pause in conversation to verbally summarize what I'd heard. Towards the end of my summarizing talk turn, I asked Chris to say more about helping kids make friends. Chris did so, specifically referencing his home community experience as a preschool teacher:

> Becky (Facilitator): ...Chris talked about helping them make friends in this camp where they might not know any other kids, right Chris? And where, if they're little – they might not know [how] or have a lot of practice making friends. Actually Chris, I wonder if maybe you would be willing to talk a little bit more about some strategies that you are anticipating using or that you use in your other job about how to help kids make friends in those first kind of nervous moments?
>
> Chris: Yeah, sometimes it's just as easy as exposing the awkwardness and learning through the discomfort of that. Icebreakers are a huge thing, even with the handful of us

> [in this group]. We all introduced ourselves, give a little background, and that deal, and that puts a little familiarity with the faces as we're talking. So the same goes for the young ones where it might be as simple as having everybody line up in a circle and taking off their shoes and when you say a word everybody has to run to a different pair of shoes. And then if you get same shoe or what not, you have to say something about yourself. It could be stuff as simple as if you have a dog or if you like French fries. ..."Oh, I like French fries too!" and then it's, right there you've got a commonality. Because even myself when I'm making friends, it's a lot easier to make friends when you've got something in common, cause you already have something to talk about, so helping them establish common ground quickly. In the preschool, it totally helps, when two kids get super jazzed up about something, they can go make some "music" together. (Meeting 1, March 31, 2017)

George followed this talk turn by sharing his own strategy for getting to know his campers and that he believed helped his campers get to know each other, an activity that I later observed him use in his camps, but which was not a strategy used by any of the other instructors in this project. Following George's shared strategy, Matthew shared his own strategy for getting campers to work together by giving them a challenge to solve. All three of the shared strategies in this boundary crossing episode are ones that encourage characteristics of productive out-of-school time STEM programs. Chris's goal to support his campers socio-emotional skills through explicit friend-making activities helped to "engage young people intellectually, socially, and emotionally" by establishing "a supportive learning community" (NRC, 2015, p. 15). George's background information gathering activity, as he used it, helped support a learning environment which accommodated "young people's interests, experiences, and cultural practices" (NRC,

2015, p. 15) by helping him to know and understand what those interests and experiences were. For example, one of the questions that George asked his students is if they have any prior experiences with coding and if so, what those experiences were (Observation, July 17, 2017). He then uses this information to differentiate instruction based on campers' experiences, a teaching practice that allows each camper to build on what they already know, rather than learning the same information again, and to do so in a learning space in which using peers as resources is highly encouraged. Matthew's strategy of solving practical challenges as an icebreaker activity supports similar productive criteria for learning in out-of-school settings by providing "first-hand experiences with phenomena and materials" (NRC, 2015, p. 15).

While neither Chris's initial talk turn about making friends prior to the start of this boundary crossing episode, nor Matthew's talk turn that closed out this episode, were identified as explicit shared prior experiences, both were tagged with the tracer "making friends" which allowed me to track the development of this idea across data sources. Collectively, these talk turns bounded together are an example of instructors engaged in boundary crossing activities through the sharing of experiences from their home communities. These instances of boundary crossing between disparate home communities and a shared professional development community provide opportunities for all instructors present to reflect on their own practices, discuss potentially new-to-them practices, and possibly use these shared practices to inform their own teaching practices.

In the following meeting, I took up Chris's idea about icebreakers and began Meeting 2 with an icebreaker activity appropriate to the online meeting context, where I asked participants to share what animal they would be if they could be an animal and why they chose that particular creature. Unfortunately, Chris was unavailable to attend that meeting, but the other participants,

with the exception of one who declined to participate, enthusiastically responded. While I did not observe any of the instructors using this particular activity during summer camp instruction, Margaret mentioned that she had used this animal icebreaker activity during her first week of camp (Post-interview, June 15, 2017). Chris, in his final interview, told me about one of his campers who was sad at the end of the camp week because he wouldn't get to see his camp friends ever again. Chris's reaction was to "stop everything and we exchanged phone numbers, everybody" (Follow-Up Interview, August 1, 2018), an action that supported his fore-fronting of socio-emotional support of his campers as an instructional goal.

Sarah, who was not present for Meeting 1 when this boundary crossing episode occurred, but was present for the icebreaker activity at the beginning of Meeting 2, told me during her post-interview that she wanted to make some sort of fun game icebreaker for the start of her younger-kid camps. She wanted it to be about geology-related content and help kids get to know each other, to "hopefully bring the shy ones out a little bit, draw them out a bit earlier in the camp than I was able to do last year. Maybe get some friends going…" (Post-interview, May 30, 2017). I was later able to observe Sarah's created game, where at the very start of camp each day, she would have her campers stand in a circle. She would point to a camper, say their name, then say a type of rock (e.g., sedimentary, metamorphic, igneous). The camper, as well as the two children directly adjacent to that camper, would work together to act out that rock type. Then the camper originally chosen would pick another child in the circle, say their name and a rock type for them to act out. This process would be repeated until everyone had a turn, and then Sarah would yell out a catastrophic geological event for everyone in the group to act out, signaling the end of the game. In her follow-up interview, Sarah shared a story of a child who was very reluctant to come to camp, insistent that he wouldn't have any friends. After playing the rock cycle game though,

he ended up “best friends” with the child who had been next to him during the game. She was thrilled that her icebreaker game had served one of its intended purposes and helped a child feel more socially comfortable in the camp environment (Follow-up Interview, August 4, 2017). So even though Sarah wasn’t a part of the boundary crossing episode at which Chris first brought up the idea of making friends as an instructional goal, her participation in the icebreaker activity in a subsequent meeting, in addition to conversations during the remaining meetings, interviews, and during camp observations in which members of this group (myself included) reified this “making friends” idea into a boundary object, became part of her enacted instructional goals for the summer as well.

While the evidence shared above strongly supports this boundary crossing episode as a site for learning for this group of informal STEM educators, the most direct evidence of Chris’s impact was shared by Margaret and Alex. Margaret, in her follow-up interview said,

> Actually, it was really interesting to hear the guy [Chris] talk, who worked with little, little kids. Because in a way, he was talking more about the raw stuff of how people learn... He wasn’t worried if they mastered a certain amount of content. Just, “How did they learn and how do you make it fun for them… I really enjoyed listening to him because his comments were so focused on how to improve learning.” (Follow-Up Interview, August 8, 2017).

Margaret, as an instructor with no formal training about how children learn, appreciated Chris’s perspective on teaching goals. Margaret’s comment was notable not only because it demonstrates the impact Chris’s shared experiences and ideas had on other participants, but also because it highlights that, in the context of a professional development meeting, participating in a discussion is not the only measure of engagement. Margaret did not speak during this boundary

crossing episode, but she was present at the meeting. George may have also been affected by Chris's instructional goal, as Alex reported that it had been George's idea to have the campers snack together outside after camp switches in order to foster friendships (Instructor Observation, July 20, 2017).

Alex was another instructor who explicitly identified Chris's ideas as being productive, despite initially saying that she couldn't think of any aspects of this professional development that were useful to her, as a classroom teacher who does this work every day. She then followed up by saying that she found Chris's "younger kid advice to be a little bit more helpful" because "he had some insight into how to make the young ones focus a little bit better"(Follow-Up Interview, August 7, 2017). Teaching camps with children from the younger age-groups was something she "struggled" with, as a teacher whose main experiences had been with middle and high school-aged young people. Alex, like Margaret, also hadn't verbally participated in the discussion during the boundary crossing episode, but through this self-report, demonstrated that moments like this boundary crossing episode served as sites for learning for her.

Introducing STEM vocabulary: A Counterexample

While I've shared two instances of boundary crossing episodes that served as sites for learning, as defined by changes in practice, for informal STEM educators and informed instructors' practices, there were also boundary crossing episodes that had great potential for serving as sites for learning but for which there was no evidence to indicate that the prior experiences shared during a boundary crossing discussion informed instructors' teaching. The most notable example of this occurred in Meeting 1, after the group had watched a video of children in an out-of-school learning environment. After a pause in the conversation, I asked the other members of the group what they thought about the instructor in the video introducing a

science vocabulary word early on in instruction rather than introducing it at some other point in the activity. I also shared my personal teaching practice around introducing new science vocabulary, based on my experiences as a teacher and as a science education researcher in an effort to broker participant's sharing. This topic is one that is frequently discussed among science educators and has been a prime topic in other professional learning communities I've facilitated. Nicolaus then described research findings from an article he had read by Brown & Ryoo (2008) regarding this problem. Since this was an article I was familiar with, and because Margaret had previously asked me to share with her any research literature related to teaching practices, I put the article into our shared Google folder right then and let the participants know that I had done so. George then talked about introducing new terms through the context of video game design and computational thinking patterns, which he was familiar with from the university research project he worked on and through his teaching experiences. Chris made a comment clarifying George's practice around introducing terminology, which George then expanded on. The boundary crossing episode ended when Chris indicated he understood George's point.

This boundary crossing episode shared many of the same traits as those presented in the vignettes: an complicated problem, multiple speakers, multiple shared prior experiences, a fairly high number of talk turns (N=17), and related to teaching, in the category of teaching practices. However, unlike the positive boundary crossing episodes described previously in these findings, the topic and tracers assigned to this boundary crossing episode ("introducing STEM vocabulary" and "Bryan Brown article") never appeared in any of the interviews or were explicitly observed. This boundary crossing episode was the only one that was categorized as related to teaching, but which had zero associated tracer codes.

Most of the boundary crossing episodes fell somewhere between explicitly productive sites for learning and not. None of the boundary crossing episodes or associated tracer topics were considered as being abjectly detrimental to teaching practices. However, this may be due to my experience as a facilitator and teacher educator in that if I felt that a topic was being deficit-framed or was inappropriate, I would take action to reframe the conversation or move on to a different topic, as appropriate. One possible example of this can be seen in the discussion during Meeting 4 around autistic children in summer camps. I have previously worked with instructors who view children with learning challenges as problematic in a summer camp setting. So, when this topic arises in meetings, I tend to frame the challenge as "How can we support these children in having a positive camp experience", rather than "How can we manage these children?", and encourage instructors to draw on existing resources to do so. However, I also acknowledge in hindsight, that in mitigating these potentially uncomfortable topics, it is also possible that I minimized additional opportunities for learning by not creating space for and recognizing moments of productive tension (Star, 1998).

Summary of Findings

In the chapter above, I have described in detail three instances in which instructors' shared prior experiences resulted in productive boundary crossing episodes, and one instance in which a boundary crossing episode did not appear to inform teacher practices. Given that there were 67 identified boundary crossing episodes identified across all five meetings, this indicates that most instances of boundary crossings fall into a gray area of productiveness in terms of being sites for learning and informing instructors' teaching practices. The vignettes shared are intended to be representative of the data corpus, but not all-encompassing. However, it is clear from the analyses that in some exemplary instances, likely those in which instructors are familiar with each other and in which the discussion is focused on emerging problems of practice,

boundary crossing activities can be very productive sites for learning for informal STEM instructors. These potential sites of learning build on instructors' varied home communities and professional backgrounds. The majority of the boundary crossing episodes that occurred provided opportunities to learn about teaching in informal spaces, drawing on research-based teaching practices as shared by the facilitator, and on the varied and rich professional experiences of the instructor participants. Designing professional development activities that support the potential for boundary crossing spaces and that allow for the existence of productive tensions in conversations is beneficial and encourages rich interactions and experiences for informal STEM instructors.

CHAPTER V

DISCUSSION

The purpose of this dissertation research was to study an online professional learning community of informal STEM educators that was designed to provide a more in-depth, ongoing professional development alternative to the typical one-time training options provided for summer camp instructors. By studying the interactions between these seasonal STEM educators, I have shown how they drew on their personal and professional experiences, and in what ways these rich interactions informed teaching practices. In this chapter I will summarize and discuss the main findings of this research, including implications for these findings to the field of informal STEM teaching and learning.

I will first discuss how the design of the professional development meetings did or did not support boundary crossing activities, why certain professional development activities better supported boundary crossing activities, and how those findings can be used to inform the design of future iterations of this model of professional development. Two specific aspects of the design of the professional development meetings will be discussed in detail: the management of the group by a facilitator, and the online context using Google Hangouts. In the following section I will discuss the analytic concept of home community and how my findings show that learning opportunities for instructors developed from sharing prior experiences around teaching more so than from non-teaching backgrounds. While the analyses for this study focused on understanding the trajectory of learning and implementation of boundary crossing episodes, there remains the question of how opportunities for learning develop within and from individual boundary crossing episodes, which I will discuss in a following section. Finally I will discuss the limitations and possible implications of this study.

Design of the Professional Development Meetings

The analyses indicate that overall, the design of the professional development activities provided opportunities for instructor participants to learn from other participants through discussion that included shared prior experiences. Discussions during the professional development meetings that included instances of participants sharing prior experiences from other communities were identified as boundary crossing episodes. The professional development activity that demonstrated the most promise in producing such boundary crossing episodes was the Brainstorm activity in Meeting 5. This was a key finding for several reasons, the implications of which should be considered in the design of future iterations of similar professional development meetings. First, the Brainstorm activity took place in the final meeting of the series, after the instructors had already met several times. This supports previous research findings that professional developments are more effective when they are long-term (Desimone, 2009). Second, the Brainstorm activity was structured quite differently from previous activities, in that the main topics and resources used were drawn directly from instructors' emergent problems of practice embedded in imminent summer camp instruction, rather than from hypothetical, facilitator-proposed, problems of practice based on other teaching contexts. While, as the designer of these professional activities, I was aware of the research findings which support such embedded topics in professional development meetings, including the use of teacher-video and reflections (Sherin & van Es, 2002; Patrick, 2017), the newness of this community constrained the interactions of participants in such a way as to mitigate the use of such professional development activities. However, by focusing on challenges that emerged while doing pre-summer camp instruction work, such as curriculum design, instructors were able to engage in activities similar to those which have been previously identified as productive for informal

teacher learning (Ash et al., 2012). Thus, the findings from this study, which are in alignment with previous studies on the effectiveness of long-term, embedded professional development, indicate that future designs for professional development for informal STEM educators should not be restricted to the typical one-day, one-week long, or other short term one-off learning experiences (Desimone et al., 2002; Luft & Hewson 2014). While I continue to be cautious in asserting that research findings from K-12 teacher professional development are applicable to informal STEM educators, in this aspect regarding the timing and situatedness of the professional development, the findings of this study follow those prior research findings. Future professional developments of informal STEM educators should be enacted over longer periods of time, ideally encompassing the months leading up to and through summer camp instruction, as well as including activities that are embedded in the context of individual institutions as much as possible.

Beyond the alignment of the findings with existing research-based professional development design recommendations for both K-12 and informal STEM educators, I found that the boundary crossing episodes that encompassed the Brainstorm activity addressed problems of practice that were both unique and more nuanced than the more generic problems of practice discussed during the prior meetings. It is possible that these unique and nuanced situations raised by instructors at this later point in the meeting series and after more common problems of practice had been discussed, lead to the necessity of drawing more broadly on the instructors' prior experiences. These situations or ill-defined problems were messy with no apparent and obvious solutions, despite informed contributions from experienced and knowledgeable educators from both formal and informal contexts present. Emergent problem spaces are valuable because they require participants to coordinate and develop new meanings as they

negotiate across representational infrastructures from their widely varied personal and professional communities (Hall & Jurow, 2015; Star, 1999).

Informal STEM educators, particularly those employed seasonally, have more varied professional experiences and less homogenous education than teachers in K-12 settings. In addition, because of the less structured nature of out-of-school learning environments, informal science instructors are often dealing with less predictable teaching challenges. Informal teaching environments, while structured, are intended to be learning spaces that are reactive to individual student interests and experiences (NRC, 2015). So informal STEM instructors are addressing unique teaching challenges, and are doing so by drawing on heterogeneous backgrounds, possibly in way that K-12 teachers are not able to due to their standardized education. While the data collected during this study, which included only a single professional learning community of informal STEM educators, is not sufficient to analyze this conjecture further, this premise could be utilized in the future design of professional learning activities for informal STEM educators.

Facilitation of the Professional Learning Community. As with other aspects of the design of this professional learning community, I drew on previous research as well as my personal and professional experiences while acting as a facilitator. Blitz (2013) identifies the presence of a facilitator or moderator as a key tenet of productive online communities. The facilitator is often someone with who is a recognized leader, such as a professional facilitator, veteran teacher, or mentor (Blitz, 2013). While I was previously unknown to the group of instructors, I had prior experience leading online professional learning communities, had significant experience as an informal STEM instructor, and had the support of the Science Discovery administration in my role as a knowledgeable and experienced facilitator. In addition

to these professional communities, I was also the parent of two daughters situated in the demographic of children served by Science Discovery. I intentionally and explicitly drew on my experiences from all of these communities to broker interactions and develop new representational infrastructure in this professional learning community (Star, 1999).

The facilitator's role is to direct the conversation by posing questions, providing relevant resources, responding to questions, bringing multiple diverse participants into conversations, and maintaining social norms for participation (Levy, Eisenkraft, & Fields, 2016). The role played by the facilitator is important in any online community, but especially so in one that is new; to have a knowledgeable person whose primary responsibility is to direct the shared work and discussion. In my role as researcher-facilitator of this community, I intentionally used my knowledge about instructors' backgrounds to enrich conversations about common problems of practice, often explicitly inviting individual instructors to talk about their experiences in discussions related to their area of expertise, as I did in Vignette Three with Chris. In doing so, I brokered interactions between these participants, both in the professional development meetings and afterwards, during camp instruction. This was in addition to my intentional and explicit modeling of sharing prior experiences during the professional development meetings, as described in the findings. These facilitation actions were intended to support the development of interactions between community members that focused not on myself as the expert and ultimate holder of knowledge in the group, but rather focused on interactions that were situated in problems of practice and driven by the instructors as learners (Bevan & Xanthoudaki, 2008; Tran & King, 2007). In the findings, I described how I positioned myself as a (former) STEM instructor, drawing on the Vygotskian (1978) idea of acting as a more knowledgeable other to

help broker instructors movements through their individual Zone of Proximal Development in regards to learning about high quality informal STEM teaching practices.

While I was reluctant, as a researcher, to intervene in the natural course of events during observations and interactions, I also recognized that my position allowed a broader understanding of the "puzzle pieces" involved in a summer camp organization. I recognized that if I could connect participants with resources to support their teaching that it was in the best interest of the instructors and the children they taught to do so. Hence my overt actions described in Vignette Two, when I suggested that Alex talk to George about a possible camp switch. My ability to serve as a broker, due to my dual roles as researcher and facilitator, allowed me the ability to provide a unique link between members of this professional learning community (Akkerman & Bruining, 2016).

There were other instances throughout the teaching observation period when I was asked by participants to give them feedback on their instruction or for help in designing camp activities. Sarah, for instance, specifically asked me to provide feedback around the camp activity in which she and the campers collaboratively decided on class behavior guidelines. We had watched a video of an experienced Science Discovery teacher leading this kind of discussion during one of our video observations as a group, but Sarah remained concerned about her ability to conduct a similarly productive discussion with her own campers. By asking me to observe her, she was acknowledging me as a more experienced colleague whose opinion and experience she had come to respect over the course of the meetings. I did observe her and provided her with written feedback via email, which we discussed at a later time in person and which she mentioned in her post-interview as having been helpful in her future iterations around this conversation and others with students about behavior. A slightly different interaction arose at the

end of one of Chris's camps, when he mentioned that he was trying to find a young-child appropriate rocket activity and asked if I had any ideas. As a former physics camp instructor, a fact that participants knew about me from conversations during interviews and the professional development meetings, I did have an appropriate activity. Prior to leaving his camp that day, I sat down and quickly wrote out the directions for building a paper rocket and left him with my notes and an example rocket. At his follow-up interview, he mentioned that he'd successfully integrated that activity into his camp curriculum and appreciated my help. He, as did many of the instructors, also commented that he wished the meetings had continued while summer camps were occurring, because he would have liked the opportunity to bring challenges like this one up with the group. Having access to peers and experienced facilitators while camps were occurring could have strengthened the newly created infrastructure of this group of people and led to more opportunities for learning and informing new or refined teaching practices, as has been previously recommended in models of professional development that are long-term and situated in teaching, rather than the more typical pre-camp condensed training versions that are offered to summer STEM camp instructors (NRC, 2015; Peter, 2009).

Though in this professional learning community, the facilitator (myself) was not a Science Discovery instructor, in future models for this type of professional development, it is plausible that prior instructor participants could be facilitators for cohorts of between 6-10 instructors. As informal educators who experienced the positive aspects of participation in an online professional learning community, with some additional support in the form of curriculum or human resources, they could be considered qualified to provide facilitation services. This is one way to support the expansion of this model of professional development to an organization

that hires upwards of 50 instructors each summer season and builds on the idea of the facilitators becoming the more knowledgeable peer (Vygotsky, 1978).

There are several models to consider around the issue of scaling up the professional learning communities, each with its own constraints and affordances. Ideally, based on existing research, the findings from this study, and from reflections on the pilot project, instructors would be purposively grouped into cohorts of between 6-10 participants who would meet bi-weekly in an online forum in the months leading up to and through summer camp instruction. Initial meetings would be focused on more abstract pedagogical practices specific to teaching on informal summer camp contexts, including activities such as Think & Shares, Video Observations, Discussions around Shared Resources, and Curriculum Development. Meetings occurring closer to the start of camp and during camp instruction should be more focused on activities similar to the Brainstorm activity, that is, focused on emergent problems of practice. By intentionally shifting from abstract concepts to situated, embedded problems of practice, participants are given time to become familiar with the each other, with the flow of interactions between participants, with the potential resources offered by each participant, and with the challenges of meeting in an online environment. Each group would be led by an experienced facilitator, either a person such as myself, with prior experience leading professional learning communities, or an experienced peer.

Unfortunately, while ideal, such a model would require a significant monetary and institutional investment that is likely outside the scope of existing budgets. Alternative models that maintain as many of the ideal characteristics as possible include one or more facilitators offering optional meetings with pre-determined and advertised topics that instructors can sign up to participate in. The benefit to this model is that it requires fewer facilitators and allows

flexibility in attendance that is important in the lives of informal STEM educators who may be working multiple jobs and would still offer instructors the opportunity to engage in discussions around both abstract and emerging problems of practice. However, this model would likely result in a less cohesive group of participants that changes from meeting to meeting. As we know from this study and others, familiarity with other participants is an important factor in increasing opportunities for learning through repeated interactions. Additionally, the facilitator is unlikely to know such a large number of potential participants in depth, to the degree that that person could effectively broker such positive interactions that emerged in this study as a result of facilitator brokering.

A different model could be a modified version of the full ideal model, in which an experienced facilitator oversees a group of more experienced peers enacting pre-designed professional development modules, with each facilitator leading one or more smaller groups. While this model would still require significant institutional resources, the monetary requirement would be less than if all the meetings were independently designed and facilitated. This model of professional development would be less responsive to the needs of each cohort of participants however, a tenet of importance in situated professional learning communities. While neither of the options presented here, nor variations of such options, are ideal in terms of providing high quality professional development to such a large group of seasonal instructors, the findings from this study indicate that working towards scaling up to a model of professional development that works for this institution and these summer STEM camp instructors will ultimately benefit the children who attend these camps by strengthening instructor's teaching practices.

Online Context. There were some distinct constraints around the online platform of these professional development meetings, both to the design of the professional development

activities and to instructors' participation. First, while there existed multiple options for online hosts beyond Google Hangouts, such as Zoom or other proprietary options, I chose Google Hangouts because Google Tools are nearly ubiquitous in school environments and therefore have a low threshold of usability (Fischer & Sugimoto, 2006). Most instructor participants were already familiar with the software, thereby decreasing the time needed to learn how to use the online meeting interface, in an already constrained timeline.

In Google Hangouts, the screen either switches between speakers (a feature which can be disorienting in conversations with rapid, short talk turns) or stays locked onto one meeting participant, leaving the other attendees' video feeds shown as small rectangles in a row along the bottom of the screen. Such small pictures can make it difficult to transfer recognition of a person from an online environment to in-person recognition. This is a frequent complaint of participants about the online context and Google Hangouts platform (Swanson et al., 2015) in addition to the difficulty in reading physical cues such as facial expressions (Schoenbach, Greenleaf, Brown, & Howlett, 2016). These challenges are part of the representational infrastructure of participation in an online community. Star (1988) describes one of the dimensions of infrastructure as being most visible when it breaks down, as is the case described here. Social interactions that typically wouldn't be challenging become problematic when the infrastructure breaks down or doesn't operate in ways that people are accustomed to.

A possible solution to this technology issue, one suggested by multiple participants in this project during their final interviews, would be to integrate face-to-face meetings with the online meetings. In particular, a socially-oriented face-to-face meet-up prior to the start of the online meetings would allow participants to interact with fewer constraints in the getting-to-know-you

period and would eliminate the need for that activity to occur in the first awkward moments of the online meetings, allowing more time to attend to substantive topics around teaching.

A second constraint of the online meeting environment is the challenge of poor internet connections, which often result in low audio or video quality, another example of failure of infrastructure. This was a particular challenge for Alex in our group meetings. As mentioned during the findings, her internet connection was frequently so poor during the meetings that she kept her video off (so that we only saw an outline of a generic silhouette representing her), and during the times she attempted to speak, her audio was choppy and incomprehensible. These technical constraints led to the question of: How might Alex's participation have been different if these meetings had been face-to-face or had she had a sufficient internet connection? Might she have contributed to the group in the more substantive way that she had intended, as described during her interviews? She never mentioned whether or not the audio she was hearing from the rest of the participants was compromised. It is possible that she was not hearing other participants or myself clearly either, which would additionally constrain her interactions with members of this community.

Despite these constraints, there are numerous positive aspects to participating in an online professional development community. Dede and Eisenkraft (2016) claim that by now, online professional development and face-to-face professional development are indistinguishable in terms of being productive sites of learning for teachers. Key aspects of the online professional development that make it more tenable for informal STEM educators are the ability to participate from any physical location that has sufficient internet connectivity (e.g., a coffee shop, home, or a school classroom), the ability to share physical artifacts of practice (e.g., home community classroom set-up, books, science materials), to easily share digital artifacts in shared online

folders, and the ability to hold meetings outside of regular business hours (e.g., evenings and weekends) without significantly impacting work or family life. All of these aspects were hailed by instructors in this group as reasons why they were able to successfully participate in a longer-term professional learning community.

While there was an asynchronous tool, a private Google+ group, associated with this project, it proved to not be a productive means to continue to interact during summer camps, beyond the synchronous online meetings. I had created the group as a way to support teachers through in-the-moment issues that frequently arise during summer camp instruction, much as synchronous meetings that might have occurred during summer camp instruction would have. I encouraged instructors to post in the Google + group about emergent resources and challenges both during the months in which the professional development meetings occurred and during summer camp instruction. Each week, on Sunday (the day before a new week of camp started), I posted about what and where each of this group's instructors was teaching in an effort to connect instructors with each other. However, by the end of the summer, there were few postings, even fewer responses to my posts, and no ensuing discussions in the Google + group. Despite the failure of this tool to serve as a productive forum for conversation, in their final interviews, several participants suggested that future iterations of these professional development meetings be conducted both prior to and during summer camp instruction. This assertation by instructors that they wanted more opportunities to interact, while faced by evidence that a facilitated opportunity to do that went unused, led me to reflect on characteristics of this particular online platform that may have proved difficult or bulky to use. Following Fisher & Sugimoto's (2006) recommendations, sociotechnical tools should enrich learning experiences, not hinder them.

At the very end of Meeting 5, there was a conversation about the Google + forum where I had reminded participants of it's existence and use once again, and George asked me to explain how he would know if someone had posted without him having to spontaneously and continuously check. During the conversation, Margaret, Nicolaus, and I all talked about where to find Google+ notifications. It turns out that we all received notifications in a different manner.

In order to be productive tools, the asynchronous online platforms need to make it easy for participants to post, easy for participants to know about and read posts, and easy to follow conversations that occur within those forums. I chose the Google + forum because of it's intrinsic link to other platforms in the Google Suite of tools, including the aforementioned ease of using Google Hangouts. Google + has proved to not provide online meeting participants with similar usefulness however, both in this study and in the pilot project that occurred previously. Another possible conclusion, beyond the constraints of the online platform, is that instructors valued the social context of the synchronous meetings over the value of asynchronous interactions. Future iterations of online professional learning communities could consider the use of both synchronous and asynchronous platforms, but designers should carefully choose platforms that will allow participants as high a level of usability as possible.

Home Communities

During the framing of this study, I highlighted the potential importance of instructors' rich and varied primary communities (which I dubbed home communities) as contributing to a professional learning community as a boundary space. While the findings indicated that, to some extent, instructors did draw on their experiences in their home communities, they more frequently shared experiences based on their other teaching communities. It is possible that the distinction of drawing on a home community isn't as relevant, as is the identification and

welcoming of sharing of experiences in other communities. That experiences in other communities are highly valued in the context of professional development communities for the richness and variety they provide, which can help participants address the more challenging and nuanced embedded problems of practices, such as those that were discussed during the Brainstorm activity in Meeting 5. In this study, in an attempt to specifically understand how instructors' home communities were used in relation to their participation in a professional learning community, I artificially separated those experiences from other experiences. In practice however, the lines between participants' home communities, teaching communities, and our professional learning community were blurred in that participants themselves treated those experiences as fluid and interchangeable. Learning, as it happens in situated contexts, is the result of interactions (Greeno, 2006). These interactions, represented in this study by boundary crossing activities during professional development meetings, are based on all of each participant's personal and professional communities, essentially building a newer infrastructure both for this professional learning community and for each individual participant as they do or do not integrate their experience as a participant in this group (Hall & Jurow, 2015). Thus, while participants' primary professional communities critically inform their individual perspectives, researchers and facilitators looking to understand why heterogeneity in professional backgrounds of informal STEM educators might contribute to a rich learning environment for young people should look beyond their 'home' community to other experiences that might prove productive sources of such heterogeneity. While those experiences that are most relevant to the context at hand, like teaching experiences, might provide opportunities for learning in boundary spaces, attending to and explicitly identifying multiple individual communities would be most productive.

Christopher Hoadley, in a recent conference keynote speech (personal communication, February 20, 2018), fore-fronted the advantages of interdisciplinary research. His point was that we, as a society, do not want to be like the Borg (the fictional Star Trek society in which all individuals are linked to a single hive mind). Rather, the interactions of people with individual and varied areas of expertise, and thus differing points of view, provide opportunities for learning with and from each other. In the findings presented in this thesis, participants such as Chris, whose teaching experiences with preschoolers inspired him to share a pedagogy of practice around supporting socio-emotional growth, resulted in evidence of other instructors' teaching practices being impacted. Had this group been organized around types of camp, for example, (e.g., field camps, coding camps, young children, etc.) rather than purposively across disciplines, Chris would not have been in the same professional learning community as Alex, for instance. While several participants, in their post- or follow-up interviews mentioned the lack of similarities between camps they were teaching as being a slightly frustrating aspect of this professional learning community, they also acknowledged their appreciation of the variety of points of view, particularly when it came to solving difficult problems. So while the findings of this study showed experiences' from the teaching communities of instructors were more often shared than those from non-teaching communities, they also demonstrated the benefit of heterogeneous professional backgrounds in providing opportunities for learning, as Star (1988) illuminates in her ideas about the benefits of boundary crossing spaces. Given the positive effects on teaching practices that were the result of the boundary crossing discussed in Vignettes One and Two, when participants where involved in an activity that reflected critical tenets of research on productive teacher professional development in both informal and K-12 teacher learning environments, drawing on heterogeneous teacher backgrounds can strengthen and expand

opportunities for learning in these contexts. Focusing on experiences from a single other community unnecessarily constrains participation in a way that is not beneficial or productive for instructors.

When looking to expand learning opportunities for instructors, I must also address the question of how many boundary crossing episodes are to be expected. In this study, I found explicit evidence of 67 boundary crossing episodes, 50 of which were related to teaching and were in some way connected to instruction or reflections outside of the context of the professional learning community. However, when considering learning from a situative perspective, there may be no clear answer as to how many is enough. Rather, facilitators should strive, as I did in this professional learning community, to design activities and facilitate discussions that allow as many opportunities as possible for instructors to be the sources of information for other members of the group, with the ideal result being the coalescing of even a few rich opportunities for participants. Instead of asking how much is enough, we should ask how few are too few? If a meeting happens when the participants have had little to no opportunity to speak either to the facilitator or, more importantly, to each other, then that is an example of a meeting in which there are few opportunities for learning and for boundary crossing activities to occur. This is supported in the findings of this study when we look at the lower number of incidences of shared prior experiences within individual activities when those activities that focused more on abstract pedagogies. Looking forward to future professional learning communities, facilitators should strive to build on all of the varied communities of the participants, because the identity of each of those participants consists not of distinctly separated experiences, but rather a personal representational infrastructure created through the blending of those experiences (Star, 1988; Hall & Jurow, 2015, Cole, 2006).

Learning Opportunities Within Boundary Crossing Episodes

While the findings of this study provide evidence to the claim that participation in online professional development, with instructors from purposively varied professional communities, provides opportunities for teacher learning around high-quality informal STEM teaching practices, the question remains of how interactions in individual boundary crossings contribute to learning. Akkerman and Bakker (2011) described four types of learning mechanisms that occur in boundary crossing spaces: identification, coordination, reflection, and transformation. Further research into boundary crossing activities of informal STEM educators could look at specific learning mechanisms with individual boundary crossing episodes, as connected to outcomes in terms of informing instructor practices, to understand in more depth how interactions between instructors can lead to positive outcomes. Because I was not able to follow instructors into their informal learning spaces for the entire summer and thus did not completely capture all of their instructional practices, my results are based upon an incomplete picture of the potential transformations in teaching that may have resulted from the boundary-crossing experiences that were created from the professional learning experiences designed in this study. Additionally, a learning mechanism framework could be used to understand and develop facilitation moves used in productive boundary crossing episodes.

One such facilitation move, which can be either a designed activity or a formative response to instructor talk, is encouraging and supporting instructor reflection on individual teaching practices. Much of the research around informal STEM instructors professional development has focused on teacher reflection on practice as a productive activity to support teacher learning (King & Tran, 2017; Patrick, 2017; Schön, 1983) However, these models of professional development are typically embedded in museums or other institutions with year-

round education staff. How then can this productive professional development practice be implemented with seasonal informal STEM instructors? Findings from this study indicate that while teacher reflection on individual practice can be productive (e.g., Think & Share activities) in terms of initiating boundary crossing episodes, such activities could be more effective when enacted further along in the professional development meeting series and when embedded in individual or closely shared emergent problems of practice.

Limitations

The following section identifies limitations of this study. Due to the intensive time requirements of facilitating, collecting, and analyzing data from such instructor-centered, iteratively-designed professional development meetings, only a small number of instructors could participate in this study. Similarly, the online meeting platform used to host these meetings restricted the total number of attendees to 10 or less. For an institution that hires between 50-70 summer STEM camp instructors, these two limitations mean that the vast majority of instructors participate in limited training events, if at all.

As an individual researcher, I was not able to observe the instructors teaching in their summer camps to the extent that I would want to in order to ensure that observations encompassed critical teaching practices discussed in the meetings. For example, given the number of discussions around setting classroom expectations, ideally each instructor would have been observed for the first hour or two of a camp session. This was not possible given this limitation however.

While many of the findings are not broadly generalizable beyond the scope of this institutional context, the research field will benefit from understanding how rich and varied

instructor backgrounds can serve as assets in benefiting members of other informal instructor professional learning communities.

Directions for Future Action and Research

In a study such as this one, where there is an aspect of research-practice partnership, there are two branches to consider for future implications. First, is that of the sustainability and scalability of the design of the professional development model for the purposes of the institution, Science Discovery, for which it was designed. Looking forward, I intend to create a series of interchangeable modules for future Science Discovery staff to use in facilitating online or in-person professional learning communities for informal STEM educators. While the modules will not be intended to proceed in a specific order, based on the findings from this study, I would recommend that they proceed from more general instructional pedagogy and challenges towards more embedded and emergent topics.

Ideally, as suggested in the discussion section, former participants could become future facilitators in order to support both the sustainability and scalability of this model, beyond my participation. Future instructors will benefit from the opportunity to engage with other Science Discovery instructors and from reflection on their own teaching practices. Future iterations of this model of professional development should contain a combination of face-to-face and online meetings to support instructor interactions as much as possible and should continue through the entirety of summer camp instruction and beyond, if possible. Interactions should be facilitated by a trained staff member or experienced instructors, knowledgeable about high-quality informal STEM teaching practices and familiar with the context of this institution.

The second branch of this partnership is that of the findings from this study informing the research field of professional development for informal STEM educators, and more broadly,

teaching and learning in out-of-school contexts. All of the recommendations for future action listed above can be used to inform the research field, but particularly the sparse field of research that exists around developing a strong and effective teaching corps for more out-of-school programs not embedded in year-round education programs, such as after-school classes and summer camps. As researchers and teacher professional development specialists, we should be supporting informal STEM educators to be highly effective educators, skills that will serve them well in any profession, while they are inspiring and educating our next generation of scientists, computer programmers, mathematicians, teachers, artists, among so many more.

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APPENDICES

Appendix A: Participant Recruitment Letter

Dear [institution] Science Discovery Instructor,

I am conducting a research study on professional development for informal science educators to understand the ways in which such educators draw on their prior backgrounds in a group environment focused on teaching practices in informal science learning environments, such as summer camps. This project is supported by [institution] Science Discovery and the Center for STEM Learning.

You are receiving this letter because you expressed interest at the time of your interview with [institution] Science Discovery in possibly participating in professional development and because you are scheduled to teach a summer camp in the month of July. *Participating is completely voluntary and will have no effect whatsoever on your relationship with [institution] Science Discovery.*

In this study, you will have the opportunity to collaborate with other [institution] Science Discovery instructors, both experienced and novice, and a trained facilitator from the University of Colorado School of Education. You will have the opportunity to learn about and develop high-quality teaching practices for informal science learning environments, to develop or refine curriculum for your summer camps, and to reflect on your own experiences teaching and learning in summer camps.

There are no anticipated risks for participating in the study. The anticipated commitment is 3-4 hours per month, beginning in the Spring semester and continuing through July, 2017.

All participants will be provided with up to a [US dollar amount] stipend for their participation, paid by [institution] Science Discovery.

If you are interested in participating in the study, please contact:

Rebecca Swanson, Doctoral Candidate in Curriculum & Instruction, Science Education

University of Colorado at Boulder, School of Education

Boulder, CO 80309-0249

[###-###-####] (phone)

[email address]

Appendix B: Survey Questions

1. Name
2. What camps will you be teaching for [institution] Science Discovery this summer?
3. Do you hold an undergraduate degree? If so, what degree do you hold? Minor?
4. Do you hold any graduate degrees? If so, what degree/s do you hold?
5. What is your current occupation?

   -Teacher Elementary

   -Teacher Middle School

   -Teacher High School

   -Teacher Informal (e.g. Science Discovery or other after-school program, museum, aquarium, etc.)

   -Graduate Student

   -Other
6. What other jobs have you held previously?
7. What prior teaching experiences have you had?
8. Do you have any personal interests relevant to camps you will be teaching at [institution] Science Discovery this summer?
9. Do you expect to work for [institution] Science Discovery in future summers (e.g. 2018)?

   -yes

   -no

   -maybe
10. If so, would you be interested in continuing to be involved in or leading professional development for other instructors in the future?

    -yes

-no

-maybe

11. Is there anything else you'd like to tell me that relates to your possible participation in our professional development this summer?

Appendix C-1: Descriptions of Professional Development Meetings

Meeting 1. Meeting 1 had two primary goals: 1) To provide an opportunity for instructors to introduce themselves to each other, and 2) To collaboratively identify, based on personal teaching experiences, positive characteristics of STEM learning environments. While some of these instructors may have known each other from other projects around CU Boulder, most participants had not met each other prior to Meeting 1. This is a common occurrence among instructors from Science Discovery, due to the organizational structure of the summer camps, where instructors submit curriculum and materials lists via email approximately one month prior to the start of camps, and generally remain at their isolated campsites while the teaching assistants are responsible for supervising children as they walk to and from a centralized drop-off point. Thus, Meeting 1 was an opportunity for instructors to get to know each other and establish their individual identities within the context of this group.

After the initial introductions, I provided a description of the overall goals of this professional development, both from Science Discovery's point of view, as well as my own instructor and research-derived goals. Key in this introduction was to convey that this professional development was situated in the perspective that learning is a social activity, and thus in order for instructors to learn, they should engage in the work they are doing preparing for their summer camps with others who are doing similar work. All activities planned within the context of this professional development were intended to draw primarily on the instructors themselves as the source of information, not myself acting in the capacity of facilitator as expert. By engaging instructors in such situated, learner-centered activities, I intended to emulate the ways in which children's' learning should be framed in informal STEM learning environments.

The following sections describe and explain the design choices of specific tools used in Meeting 1.

Think & Share. This activity structure is based on a Think/Pair/Share strategy commonly used in student instruction, but adapted for use in this online adult learning environment, where the option to pair up first and share is limited by the videoconferencing software and by the relatively small size of the group (six instructors and one facilitator). Rather, I drew on the strength of the small group by allotting 5-10 minutes to quietly reflect and record individual thoughts around a specific question. The question was designed draw on each instructor's personal experiences as both learners and teachers in STEM learning environments. The question was intended to be open-ended, to allow for discussion and differing points of view, but also focused enough to compile individual thoughts into a group opinion or list of sorts, that were then used as a basis for curriculum development during Meeting 2.

Video Observation. The use of video observations has been used for professional learning in both formal and informal learning settings (Ash et al., 2012; Borko et al., 2014; van Es & Sherin, 2006) as a tool to help teachers, instructors, and floor staff reflect on their instructional interactions with children. The watching of a video clip does not, by itself, serve as a learning tool (Borko, et al., 2014; Sherin & Dyer, 2017). However, by pairing video observations with facilitated discussion and reflection, such observations undertaken in the setting of professional learning communities can serve as a rich basis for discussion around the "twists and turns" of teaching (Sherin & Dyer, 2017). Ideally, selected videos should be representative of the context in which members of the professional learning community are teaching, such as video taken in their own teaching spaces or from others within the same organization or school (Borko et al., 2014; Sherin & Dyer, 2017). In cases such as the

community being studied here, where video taken in their own teaching spaces was not possible to acquire due to the asynchronous timing of professional development and teaching enactments, the videos used were chosen to be as close as possible to the instructors' teaching context. Additionally, videos shown were intended as examples, not exemplars, of pedagogy or teaching practices, as the value of watching classroom enactments is in the noticing and discussion of interactions between teachers and students (Borko et al., 2014; Sherin & Dyer, 2017). Borko and colleagues (2014) suggest that facilitators follow three guidelines for planning to use video observations in professional development meetings: 1) determine goals for discussion and select video clips, 2) identify features of the video clip that are important to meeting the goals, and 3) crafting "back-pocket questions" to have at the ready to facilitate discussion. I following these guidelines when choosing videos for observation and discussion in these professional development meetings, noting my goals and back-pocket questions in the facilitation guide

For the purposes of these professional development meetings, I have chosen video of instructor/student interactions that take place in informal learning environments, both from publicly available video libraries and from unedited video taken during a day camp at Science Discovery. Following Borko and colleagues suggested guidelines, each video clip was chosen for it's brevity and relevance to the main topic of the meeting, with identified goals in mind, and associated "back-pocket questions" listed in the facilitation guide.

Meeting 2. The primary goal of Meeting 2 was to engage instructors in critical analysis and development of existing curriculum for summer STEM camps. This work built on the first meeting by utilizing the instructor-identified characteristics of productive informal STEM learning environments. Each instructor receives access to previously written, digitally stored curriculum archives specific to their assigned summer camps in a document referred to as the

"Instructor Road Map". As an organization, Science Discovery is in the process of trying to standardize their curriculum archives, and required this summer's instructors update their lesson plans to a proposed curriculum template and/or comment on the existing curriculum post-enactment. There were several critical challenges in this process, including: a) previously submitted curriculum is of varying quality both in terms of activities and usability, b) newer camps sometimes have no existing curriculum and only a very brief description, often only a name and an idea, c) instructors who teach the same camp over multiple years and may not have shared their curriculum with Science Discovery, and d) instructors may have little or no experience creating useable lesson plans or cohesive curriculum due to a lack of experience, feedback, or training in these skills. Thus, it was, and continues to be, both an institutional and professional development goal to develop curriculum-writing skills in these instructors.

The first activity was to have instructors collectively read through and dissect an existing piece of curriculum from a Science Discovery summer camp. I gave instructors the opportunity to pick which lesson plan to look at, from several examples recommended by Jernigan or from their own shared lesson plans. The instructors present deferred to my suggestion of Science Discovery's exemplar lesson plan, designed and written by a staff member considered to be an expert instructor. I asked the instructors to spend 5-10 minutes independently reading through the curriculum and making notes on items they identified as being particularly well thought-out or effective, as well as concerns they had about any other items, and if time allowed, to suggest improvements. This practice of dissecting curriculum is commonly used in pre-service teacher education as a precursor to curriculum revision (Davis & Krajcik, 2005; Forbes & Davis, 2010). This group reconvened and was asked to discuss observations using a whole group talk format.

The second planned activity for this meeting was to have participants give feedback on another group member's curriculum sample for a camp this summer. Such feedback would need to be given in a written form, due to the online environment. To facilitate this, I had asked each instructor to upload a lesson plan for a camp they are responsible for, prior to the start of the meeting. Due to time restraints and feedback from instructors during the course of the meeting, I instead had them look at a non-template formatted Science Discovery lesson plan to compare usefulness of curriculum.

Meeting 3. Meeting 3 was designed with the goal of providing instructors the opportunity to develop recognition and use of productive teacher talk moves as a way of supporting student learning. There is extensive literature, both in the context of K-12 science classrooms and in informal learning environments, that what and how a teacher or instructor asks questions and responds to student answers affects student learning (Lemke, 1990; Michaels & O'Connor, 2012; Zhai & Dillon, 2014). Specifically, when teachers ask questions, do those questions open up opportunities for students to engage in science talk, eliciting student thinking, or do they represent I-R-E style discourse, where the teacher is looking for the right answer?

To facilitate this goal of helping instructors reframe the questions they ask, I used two short unedited video clips taken during a single-day Science Discovery camp that happened during the same semester as this project. The first clip was shown following a discussion on the various ways that an instructor could organize or group children for instructional purposes. Michaels and O'Connor (2012) refer to such organizational structure as talk formats, identifying the following formats specifically: teacher guided whole group discussion, small group discussion, and partner talk. The clip being used was intentionally chosen not as an exemplar of an instructor's choices, but as an example of how this instructor chose to organize the children.

The intent was to prompt the instructor-participants to make a connection between the instructional goal and how the talk formats used may or may not support that goal.

Prior to viewing the second video, I shared several resources around teacher talk moves, specifically drawing on Michaels and O'Connor's (2012) Checklist for Productive Discussions and Nine Teacher Talk Moves Checklist and a document included resources compiled specifically for this group as tools to use while watching video to help identify specific teacher talk moves. After watching the video, I facilitated a discussion around observed talk moves, intentionally and explicitly using specific talk moves myself as the discussion ensued, to highlight the usefulness of this practice. Finally, I encouraged teachers to return to their lesson plans for summer camps and develop quality "back pocket questions" to elicit student thinking for use during teaching (Borko, et al., 2014).

Meeting 4. The goal of Meeting 4 was to provide teachers with the opportunity to identify and reflect on their personal motivation for teaching STEM subjects to children, both in formal and informal learning environments. I did so by asking instructors to individually reflect on their own answers to a question prompt. This prompt was revised from a similar question asked of the 2016 cohort during their first meeting. While the original prompt, listed in the facilitation guide, did result in extensive discussion around positive features of informal learning environments, the revised prompt is designed to reflect criteria proposed in a the recent NRC report on Identifying Productive Out-of-School Time Programs (2015) in addition to reflecting previous conversations that occurred for the current cohort.

Personal Reflection. Reflection on teaching practice as a tool is used frequently in both formal and informal professional learning communities. Reflection is the practice of engaging in intellectual activities which allow an individual the opportunity to explore their own personal

experiences in order to lead them to new understanding (Patrick, 2017). Ideally, for teachers using reflection as a tool for improving teaching practice, engaging in such thinking processes and being willing to question one's own teaching practices would result in an action that translates to improved student learning (King & Tran, 2017; Schön 1983). While reflective thinking is introduced for first time in this professional development during Meeting 4, it has been the basis of other professional learning communities for informal science educators over longer periods of time, as an iterative cycle of reflection and action to support long-term change in teaching practices (Ash et al., 2012; Tran, Werner-Avidon, & Newton, 2013; DeGregoria Kelly, 2009; Richardson, 2012).

It is because of this connection between reflective thinking and action that I followed-up the reflective thinking activity in the first half of the meeting with an activity that asked the teachers to recognize the criteria identified in their reflections in a video clip of a camp enactment. This follow-up was intended to allow the instructor-participants to move from abstract concepts about why STEM is being taught to concrete enactments of those concepts, as they play out in informal learning environments.

Meeting 5. Meeting 5 was the final meeting for this professional development series and was not part of the original design, which included only four meetings. As a result, the two primary goals were, 1) to discuss ways of providing ongoing support in asynchronous ways, and 2) for instructors to identify specific goals in the ongoing development of their own teaching practices.

Instructors were asked to submit questions ahead of the meeting around common instructional challenges that were ongoing concerns for them. The bulk of the conversation in this meeting was centered around these submitted questions.

Time constraints and instructor feedback resulted in an introduction of the instructor goal activity, but with instructors electing to develop their goals outside of the meeting time and submit them to me prior to their next individual interviews. Teachers who independently develop and share their goals for teaching practices are more likely to feel accountable to incorporate identified teaching practices. Additional and ongoing support of instructors as they enact new teaching practices is critical to allow for reflection and iteration. All of the instructors involved in these professional development meetings will be teaching their camps for multiple sessions, allowing for iteration of new teaching practices. The activities used in this meeting were primarily whole group guided discussions that encouraged the sharing of personal reflections, all of which were activities used in previous meetings.

Appendix C-2: Facilitation Guides for the Professional Development Meetings

Meeting 1: Facilitation Guide

Objective: Getting to know each other, coming to a shared understanding of the purpose and intent of informal STEM-oriented teaching and learning environments.

1. Getting online (10 min)
2. Introductions (20 min) - Name, CUSD classes, current job, brief background
3. Overview of Project PDISE (5 min)
4. Think & Share (30 min): What does a good informal learning environment look like to you? What are students doing? What are the instructor/TA doing? What does the physical environment look like? (Resources: Venn Diagram to share, Figure 1)
    a. Ask the question (type into Chat box)
    b. Ask instructors to take a couple of minutes to think and answer independently
    c. Ask for volunteers to share their answers/thoughts.
    d. Compile thoughts in some shared format (e.g. Google doc)
5. Video (20 min): good/bad/etc? Watch it 2x.
6. Wrap-up (10 min): How to design for these criteria when writing LP's or looking for resources?
    a. Scheduling for next time: get rough estimates of time availability, will send out Doodle poll
    b. Homework: Bring/share beforehand a typical lesson plan or piece of curriculum that you think represents some of the characteristics we've discussed today, or

your favorite resources for designing lesson plans. (Create GDrive shared folder for group)

c. Google + group

Meeting 2: Facilitation Guide

Objective: Identify and refine quality informal STEM curriculum based on previously identified characteristics.

1. Getting online (5 min)
2. Check-ins (15 min): Where are you currently in your curriculum work for Science Discovery?
3. Dissecting Curriculum (20 min):
    a. Pick one to look at together (perhaps a pre-existing one in a Science Discovery format?)
    b. Take 5 minutes to critique independently.
    c. Share outs: goods, bads, format, design of the learning environment, student activities, teacher doing?
    d. What could we do to improve this?
4. Curriculum Feedback (15 min): Pair off and give feedback to one other person about their curriculum (would have to type into comments, not shared verbally).
5. Resources List-Building (20 minutes)
    a. What are your favorite go-to places? Why?
    b. How do we know if they are good? bad?

6. Wrap-up (10 min):
    a. Scheduling for next time: get rough estimates of time availability, will send out Doodle poll
    b. Homework: Reading on Teacher Talk Moves/Formats (mini-lectures, or eliciting student thinking)
    c. Reminder about Google + group

Meeting 3: Facilitation Guide

Goals: To observe and identify teacher talk moves that elicit student thinking and discussion, particularly as they are used in informal learning environments.

1. Check-ins (10 min)
2. Agenda (5 min)
3. Teacher Talk Moves and Classroom Talk Format: Brief overview (15 min)
    a. What are the various configurations that talk in the classroom happens? Be intentionally explicit here in order to develop a common language within this group.
        i. Whole Group
        ii. Small Group
        iii. On-on-One
        iv. Student - student
        v. Student presentation

   b. For what purpose might we arrange the campers in these configurations? What is the goal of each configuration? These are design decisions that can affect student learning, important to attend to.

4. Watch Video 1 from Robots Class. (10 min)
   a. What do you notice about what the instructor is saying and how kids are responding?
   b. How is the instructor organizing kids?
   c. What is the goal of this portion of the class and do you think the talk and talk formats used achieved those goals?
5. Discuss participant observations around Video 1 (15 min)
6. Share PDISE Talk Primer (10 min) and talk through items in it. Also share Checklist for Productive Discussions and Nine Teacher Talk Moves Checklist (TERC)
7. Watch Video 2 with transcript and specifically identify teacher talk moves. (10 min)
   a. Instructors should identify specific talk moves that occur during the clip. Which ones seem to accomplish the task at hand?
8. Discuss teacher talk moves.
   a. Which ones were productive in this situation?
   b. Which ones do you see yourself using?
   c. The talk moves in the primers shared here were designed to support talk in K-12 classrooms. There is also a significant body of research around productive talk that happens in museums, but little on productive talk in summer camp or after school classes. What of these that we see here do you think are most likely to help you achieve your goals around whole group discussions in summer camps?

   d. Encourage teachers to take look back over their lesson plans and re-think configurations of talk, develop some pre-emptive questions (back-pocket questions) and think through the goal for talk episodes. (7:45 - 7:55)

9. Wrap-up (10 min):
   a. Scheduling for next time: get rough estimates of time availability, will send out Doodle poll
   b. Plan for next meeting
   c. Reminder about Google + group

Note: Curriculum [and materials lists] due to Science Discovery on May 1, 2017

Meeting 4: Facilitation Guide

Objective: Identify and develop individual criteria for purpose of STEM education, as a way of designing for productive and positive classroom cultures in summer camps.

1. Getting online (5 min)
2. Check-ins (10 min): What's going well? What could you use the groups support on right now?
3. Intro (5 min): *In the previous meetings of this group, various members have expressed that we want camps to be fun but that kids are also there to learn as well. We've been pretty focused on detail-oriented aspects of teaching in summer camps, so let's take a step back and look at the meta-view.*
   a. Why do we teach STEM subjects to kids?

   b. Why do you feel it is important for kids to have opportunities to engage in STEM learning?
   c. What is STEM to you? To Science Discovery? [This was the question I asked in the 2016 meetings]

4. Self-Reflection (10 min): Each instructor should take 5 -10 minutes to answer these questions for themselves. What is it that motivates you personally to teach STEM? Is this similar to what you think Science Discovery's goals are?
5. Sharing and Discussion (20 min): *While I asked you to answer this question mainly so that you have a sense of your own guiding principles as you engage with kids this summer, I think it would be really helpful to other people to hear about other reasoning around this. Perhaps pick one thing you wrote about that you'd feel comfortable sharing with the group.*
6. Resource: Criteria for Identifying Productive STEM Programs in OST Settings (NRC, 2015). (10 min) *What do you think about these criteria? Agree, disagree?*
   a. Abbreviated criteria here
7. Tunneling back down to the practical logistics (20 min): *How are you designing your camps to support the criteria that you have identified as important?* [I ask this question specifically because there is a degenerative tendency in summer camps to pick activities to fill time, rather than to fulfill the greater goals of the curriculum designer].
   a. Discuss: pick one activity that you've recently considered and think about how that activity fits. Describe for group.
   b. Encourage instructors to really consider the purpose of chosen camp activities and connect them to overarching learning goals.

    c. [Might consider having a video segment as backup if they aren't feeling super chatty. In which case, watch segment and ask if what is happening in the camp is filling the NRC, 2015 criteria or other criteria that have been listed today]

8. Wrap-up (10 min):
    a. Scheduling for next time: wrapping up
    b. Reminder about Google + group: *As we head into camps, I'll be using this forum to check-in with folks as you start running summer camps, asking questions about what's happening in your camps that relates to various topics we've discussed. So make sure you're a part of the group. While I love and appreciate the back-channel discussions I've been having by email, let's move those conversations to Google + so that everyone can benefit from them.*

Meeting 5: Facilitation Guide

Objective: To address participant concerns and identify personal teaching goals related to upcoming summer camp instruction.

1. Getting Online
2. Check-ins
3. Setting individual teaching goals for this summer
    a. Overview of topics and resources discussed in these meetings.
    b. Individual reflection time
    c. Sharing of goals
4. Open discussion around instructor concerns for camps.

   a. Classroom management for informal learning environments: What are the biggest challenges facing instructors?
   b. Plans to carve out time for instructor reflections

5. Closing and reminder to check Google + for ongoing discussions.

Appendix D-1: Pilot Project Interview Questions

Hi, my name is Becky Swanson, and I'm a PhD student in the School of Education at CU Boulder. I am partnering with Science Discovery to develop a training program for their summer camp instructors. I really appreciate the time you're taking to chat with me today; I only have about 7-8 questions to ask you. I'm not recording this, I'll only keep track of your responses in written/typed notes, and your responses will only be labeled and reported back to Science Discovery as [Instructor/TA/Parent]. So for example, your responses will just say "A parent said this..". We're just trying to get an idea of what the different people who participate in the program have experienced, so that we can plan the best prof development program possible that is responsive to your needs.

Do you have any questions for me before we get started?

Instructors:

1. Tell me a little bit about yourself.
2. What classes have you taught with Science Discovery?
3. What other teaching experiences do you have?
4. How long have you been teaching? with Science Discovery? Elsewhere?
5. What are some things you like about teaching at Science Discovery?
6. What are some of the challenges about teaching classes or camps here?
7. What suggestions do you have for us to help you and support you in your teaching here?

Appendix D-2: Pre-Interview Protocol

PDISE Instructor Interview Protocol

[Pre-Professional Development Meetings]

The purpose of this interview is to ask you some questions about your background and experiences, to help me understand your professional development needs as I work with [institution] Science Discovery to develop a program to train their summer science camp instructors. I might ask you follow-up questions to make sure I understand what you're saying.

I'd like to audiorecord this interview. The only people who will hear this audiorecording will be myself and a transcriber. Is that OK with you?

Before we begin the interview, I want to remind you that participating in this study is voluntary and your responses are completely confidential. At any point during the interview, if you would like me to turn off the recorder, just tell me to do so. Do you have any questions about the study before we begin?

1. Tell me a little bit about yourself.
    a. How would you describe your gender?
    b. How would you describe your race/ethnicity?
    c. What was your college undergraduate major?
    d. Have you done any graduate work? If so, what was your focus? What graduate degree or degrees did you earn?
2. How did you come to be an instructor at Science Discovery this year?
    a. What was it that made you interested in teaching for Science Discovery this year?
    b. How many years/summers have you taught for Science Discovery?
    c. What camps or classes have you taught for them previously?
    d. What camps are you teaching this year?
3. When you are not teaching for Science Discovery, what do you do with your time?

   a. Do you have other jobs?
   b. Does your work with Science Discovery relate to any other personal or professional interests you have? If so, how?
4. What other teaching experiences do you have, either in schools or in other settings?
5. What are some things you like about teaching at Science Discovery?
6. What are some of the challenges about teaching classes or camps here?
   a. How is teaching for Science Discovery different for you than your other teaching experiences? How is it similar?
7. How would you describe yourself as a science teacher?
8. How do you think children learn science best?
9. Tell me about how you go about developing or adapting curriculum for use in summer camps.
   a. How do you get started?
   b. What are your favorite resources? Why?
   c. What are the biggest challenges you face?
   d. What parts of curriculum design do you feel confident in?
10. What suggestions do you have for us to help you and support you in your teaching here?
11. Is there anything else you'd like to tell me?

Appendix D-3: Post-Interview Protocol

PDISE Instructor Interview Protocol

[Post-Professional Development Meetings]

The purpose of this interview is to ask you some questions about your background and experiences, to help me understand your professional development needs as I work with [institution] Science Discovery to develop a program to train their summer science camp instructors. I might ask you follow-up questions to make sure I understand what you're saying.

I'd like to audiorecord this interview. The only people who will hear this audiorecording will be myself and a transcriber. Is that OK with you?

Before we begin the interview, I want to remind you that participating in this study is voluntary and your responses are completely confidential. At any point during the interview, if you would like me to turn off the recorder, just tell me to do so. Do you have any questions about the study before we begin?

1. Tell me about how you went about developing or adapting curriculum for use in this year's summer camps.
    a. How did you get started?
    b. What were your favorite resources?
    c. What were the biggest challenges you faced?
    d. What parts of the curriculum design and planning do you feel confident in? What parts are easiest for you? What parts do you enjoy?
2. What aspects of the professional development meetings felt most useful to you in getting ready for teaching for Science Discovery this summer?

3. What are some things you are excited about teaching or doing with the children in your camp?
4. What are some of the challenges that you are anticipating for this summer?
5. How would you describe yourself as a science instructor?
    a. What kinds of teaching practices do you prefer or have planned to use for this summer?
6. How do you think children learn science best?
    a. What kinds of activities have you planned for this summer that you think support this kind of learning?
    b. What kinds of activities would you have like to have planned, but did not yet?
7. What suggestions do you have for us to help you and support you in your teaching here?

Appendix D-4: Follow-Up Interview Protocol

PDISE Instructor Interview Protocol

[Follow-up, after completion of summer camp instruction]

The purpose of this interview is to ask you some questions about your background and experiences, to help me understand your professional development needs as I work with [institution] Science Discovery to develop a program to train their summer science camp instructors. I might ask you follow-up questions to make sure I understand what you're saying.

I'd like to audiorecord this interview. The only people who will hear this audiorecording will be myself and a transcriber. Is that OK with you?

Before we begin the interview, I want to remind you that participating in this study is voluntary and your responses are completely confidential. At any point during the interview, if you would like me to turn off the recorder, just tell me to do so. Do you have any questions about the study before we begin?

1. Tell me about how summer camp went.
    a. Overall, did you feel like camp was successful? In what ways?
    b. Tell me about an activity or day that went really well.
    c. Tell me about an activity or day that felt like a negative experience for you or the campers.
    d. Tell me about an activity or day that did not go as expected or as planned. Was that a positive or negative experience for you and/or the campers?
    e. What were some of the challenges that you experienced this summer?
2. In retrospect, what aspects of the professional development meetings seem to have been most useful to you in getting ready for teaching for Science Discovery this summer?
3. In what ways or by which people did you feel supported during your work at Science Discovery?

4. How would you describe yourself as a science instructor?
    a. What kinds of teaching practices did you find yourself using most often this summer?
5. How do you think children learn science best?
    a. What kinds of activities did you find to be the most successful in engaging students in science learning this summer?
    b. Were there any activities that you hoped would tap into this, but fell flat? [If so] Can you describe them? Any conjectures on why they did not work out as hoped?
6. Do you think that any of the skills you've used or developed while teaching for Science Discovery will be useful to you in other areas of your life, personal or professional?
7. What suggestions do you have for us to help you and support you, and future instructors, in your teaching here?
8. Is there anything else that you'd like to share about your participation in this project?

Appendix E: Sample Data Log Including Emergent Topics and Tracer tags

Excerpt Identifier [PD#_BCexcerpt#]	Official Topic of Conversation (OTOC)	PD Activity	Emerging Topic of Boundary Crossing Episode	Possible Tracers
PD1_BC1	Introductions	Introductions	None	
PD1_BC2	What does a good summer camp space look like?	Think & Share	Attending to Basic Human Needs	Bathroom, Snacktime, Comfortable rooms, temperature
PD1_BC3	What does a good summer camp space look like?	Think & Share	Clickers/Plickers	clickers/plickers
PD1_BC4	What does a good summer camp space look like?	Think & Share	"Icebreakers"	icebreakers, making friends
PD1_BC5	What does a good summer camp space look like?	Think & Share	"Growth Mindset"	growth mindset

Appendix F: Boundary Crossing Episodes Not Fully Analyzed

Boundary Crossing Episode Identifier [PD#_BCE#]	Official Topic of Conversation (OTOC)	PD Activity	Emerging Topic	Possible Tracers	Teaching Practice: yes/no	# of PE's	Participants: Prior Experiences	Participants who spoke	Non-Speaking Participants	# of talk turns in excerpt
PD1_BC1	Introductions	Introductions	None		no	8	All Present: Becky, Nicolaus, Alex, Chris, Matthew, George, Margaret	All Present: Becky, Nicolaus, Alex, Chris, Matthew, George, Margaret	none	27
PD1_BC5	What does a good summer camp space look like?	Think & Share	"Growth Mindset"	growth mindset	YES	1	Alex	Alex	Becky, Chris, George, Nicolaus, Matthew, Margaret	1
PD2_BC1	Introductions	Icebreaker	Getting to know other participant	Icebreaker (this activity happened because of the discussing in PD1_BC4), Chasing Coral, Geology Dept. at CU	no	3	Sarah, George	Sarah George Becky	Margaret, Alex, Nicolaus	26
PD2_BC2	Introductions	Icebreaker	Crows	Crows	no	1	Margaret	Margaret, Nicolaus, George, Becky	Alex, Sarah	10
PD2_BC3	Introductions	Icebreaker	None	declined to participate	no	1	Nicolaus	Nicolaus, Becky	Margaret, George, Alex, Sarah	4
PD2_BC19	Curriculum Development	Wrap-up	Lesson Plan Details: Resources & Writing Curriculum for Others to Use	Resources, Last-years PDISE group, Exemplar LP from Eric.	YES	1	Becky	Becky	George, Nicolaus, Alex, Margaret, Sarah	1
PD3_BC1	Greetings	None	Using K-12 research to inform	conference, k-12 research	YES	1	Becky	Becky	Chris, George, Sarah, Margaret,	1

PD3_BC2	Check-in	Check-ins	Volunteer Teaching outside of 'home' community	Volunteer teaching outside of normal setting	YES	1	Alex	Alex, Becky	Chris, George, Sarah, Margaret	4
PD3_BC3	Check-in	Check-ins	Submission of Master's Thesis	accomplishment, Master's thesis	no	1	Sarah	Sarah, Becky	Chris, George, Alex, Margaret	4
PD3_BC4	Teacher Talk Moves & Classroom Talk Structure	Video Observation & Discussion	Context Around Video	CUSD Robots Class, videotape quality	no	2	Becky	Becky, George	Chris, Alex, Margaret, Sarah	9
PD3_BC14	Teacher Talk Moves	Video Observation & Discussion	Context Around Video		no	1	Becky	Becky	George, Margaret, Alex, Sarah, Chris	1
PD4_BC2	Greetings	None	Teaching K-12 after earning a doctorate	Earning a Doctorate, PhD	no	2	Becky	Nicolaus, Becky	Sarah, Chris, Margaret, George (? picture, but having connection issues)	4
PD4_BC6	Why is teaching STEM important?, Why do you teach STEM?	Think & Share	Getting Every Kid Involved	Teaching STEM	YES	1	Becky	Becky	Chris, Sarah, Nicolaus, Margaret, George	1
PD5_BC1	Greetings	None	"Dark Web"	Dark Web, Book: Future Crimes, Bitcoin	no	1	George	George, Becky, Nicolaus	Margaret, Sarah, Chris, Alex	14
PD5_BC2	Check-in	Check-ins	Terrell Davis Induction Tix	Terrell Davis, Football	no	1	Alex	Alex, George, Becky	Margaret, Chris, Sarah, Nicolaus	13
PD5_BC3	Check-in	Check-ins	Hawaii	Hawaii Sunrise Sunset	no	1	George	George, Becky	Margaret, Chris, Sarah, Alex, Nicolaus	11
PD5_BC10	Wrap-Up	Wrap-up	Communicating with PDISE Group	Gmail, Google +, GroupMe, Group Texts	no	3	Margaret, George, Becky	Margaret, Becky, George, Nicolaus	Nicolaus, Alex, Sarah, Chris	54