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TEACHER-TO-TEACHER MENTORING AS PROFESSIONAL DEVELOPMENT: USING AUTHENTIC SCIENTIFIC RESEARCH AS A MEDIUM

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ABSTRACT

Contemporary science education reform movements stress the importance of the professional development of teachers as an avenue for facilitating teacher change. Educational research on the professional development of teachers often focuses on the effect of hierarchical approaches on teachers enacting an authoritative perspective. Little understanding exists about the professional development of teachers that is non-hierarchical. This thesis explores teacher-to-teacher mentoring as professional development in the context of science research experiences.

The participants in this study were teachers involved in the National Science Foundations' (NSF) Teachers Experiencing Antarctica and the Arctic (TEA) program. This study examines meaningful interactions between three mentor teachers (i.e., TEA teachers) that participated in authentic scientific polar research and twelve protégé teachers (non-TEA teachers) that resulted in teacher change. The research questions that guided this study were:

1. How do meaningful interactions among teachers occur?
2. How do teachers describe professional collaborations associated with authentic science research experiences?
3. What elements of interactions among teachers are meaningful?
4. Why are these elements of interactions meaningful to teachers?

Grounded theory was the analytical approach used in this study within the context of naturalistic inquiry. Theoretical sampling required simultaneously interviewing participants, coding, and data analysis. Data analysis revealed three categories that described the participants mentoring experiences: (a) actions, (b) interactions, and (c)

engagement results. Each incident of mentoring is an engagement that comprises participant action and interaction.

The findings indicate that engagements that involve synthesis actions and dialogic interactions are meaningful to participants and result in teacher change. These types of engagements occur when participants have ownership in an engagement. The findings also suggest a cyclical relationship between teacher change and engagements. Teachers that experience change to their practice may participate in further professional development engagements. This study has implications for teacher professional development, program policy, and education research.

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EPIGRAPH

Not all who wander are lost.

J.R.R. Tolkien

Chapter 1

Purpose of the Study

Introduction

The goal of changing teachers' practice is to improve the education of students. Yet, a concrete model of effective teaching practice does not exist (Dunn & Shriner, 1999). Even though classroom teaching is an ill-structured domain, Dunn and Shriner found that highly competent teachers exhibit characteristics analogous to experts in other fields (e.g. professional athletes and musicians). One way high levels of competency were reached was through deliberate practice in teaching, i.e., taking advantage of opportunities for learning and increasing proficiencies with pedagogy (Darling-Hammond & Baratz-Snowden, 2007). Dunn and Shriner (1998) found, "…that teachers perceived discussions with other teachers as highly relevant to improving their teaching effectiveness." (p. 644). This observation reinforces the importance and effectiveness of collegial collaborations.

Both state and national reforms suggest changing teaching practices (National Research Council, 1996). How these reforms materialize in the classroom often varies from the intent of such reforms. Darling-Hammond (1998) report, "district staff development is still characterized by generic one-shot workshops that have very little effect on practice rather than more effective approaches that are curriculum-based, sustained over time, linked to concrete problems of practice, and built into teachers'

ongoing work with their colleagues." (p. 9). The reason for deviations from the design of reforms is the fact that teachers are the principle agents of transforming classroom practice. Yet, Darling-Hammond (1998) report, "[t]wo thirds of teachers report that they have no say in what or how they learn on the job." (p. 9).

Spillane (1999) argued the importance of zones of enactment playing a pivotal role in teachers' implementation of instructional reform. Spillane defines zones of enactment as, "…that space where reform initiatives are encountered by the world of practitioners…" (p. 144). Teachers who were successful with changing their classroom practice to align with reform incorporated other teachers in their zone of enactment. In other words, teachers that tackled reform collaboratively with colleagues were successful in changing their classroom practice (Cole & Zembal-Saul, 2002).

Collaborations between teachers are an important component of professional development, but the answer to the question of how teachers learn is still elusive. The literature on teacher learning is nebulous and rarely links teacher learning to changes in teacher behavior (Wilson & Berne, 1999). Wilson and Burne suggest, "…teacher learning requires some disequilibrium and that important teacher learning emerges only from occasions when teachers' extant assumption are challenged." (p. 200). This statement correlates well with contemporary cognitive research (National Research Council, 2000). Yet teachers may resist expressing their assumptions with colleagues because society views them as experts in content and pedagogy.

From my experience working with teachers, it is taboo to admit not understanding what you are teaching or how to teach it. Part of this resistance may be a manifestation of the school culture (R. Putnam & Borko, 2000). Wilson and Burne (1999) offer,

"…teachers have very little experience engaging in a professional discourse that is public and critical of their work and the work of their colleagues." (p. 181). Overcoming this challenge requires trust built over time. Again, this suggestion for professional discourse confronts traditional forms of professional development that are prescriptive in nature. Instead, professional development must offer teachers opportunities to learn through collective inquiry into challenges grounded in the classroom – e.g., problems of practice.

Teachers welcome increased dialogue with their colleagues, but the majority of the school day is spent alone interacting with students. This isolation is especially true for high school teachers who focus more on content and, in contrast to elementary school teachers, less on the development of children. Further, middle school teachers are more likely to have joint planning time structured into their daily schedule compared to high school teachers (McEwin et al., 1996). Even elementary and middle school teachers find that the majority of their time is spent away from their colleagues. In an effort to erode this isolation and its effects on teacher practice, some professional development efforts focus on teacher collaboration (Dawkins and Dickerson, 2007). Exposure to these professional development models offers insight into the culture of the classroom teacher and what conditions may facilitate interactions among teachers.

Many professional development programs for science teachers are invigorating but costly (Bacon, 2000). The investment of any meaningful professional development effort can be justified if it has an amplifying effect. For instance, the cost of a teacher involved in a Research Experience for Teachers (RET) for a summer can easily exceed $5000. Assuming the experience has a positive impact on that teacher's students immediately give preliminary support to the investment. But, if the teacher can also use

that summer experience as a catalyst for meaningful professional development of other teachers that promotes teacher change the initial cost becomes even more digestible.

Marx et al. (1998) support this reasoning with, "[t]eachers are enacting innovations in their classrooms and they have become change agents in their schools and in the State's science teachers' organizations." (p. 674). Teachers involved in change must have a means for sharing this change for any amplification to occur. One manner in which this can take place is through teacher-to-teacher mentoring.

Traditional professional development does not align with the needs of today's teachers. Furthermore, top-down professional development models are fragmented and do not align well with constructivism. Professional development models that do hold promise reduce the isolation of teaching through collaborations that are grounded in the practical knowledge of teachers (Borko, 2004).

Professional development efforts that offer teachers authentic experiences to increase their content knowledge and understanding of the nature of science result in changes to those teachers' practices (Dresner & Worley, 2006). What is absent in studies about research experiences for teachers is an assessment of how the professional development may transfer to teachers that did not directly participant. If a model for professional development among teachers existed, the impact of research experiences for teachers may multiply.

Primary Goal of the Dissertation

The primary goal of this dissertation is to develop a preliminary professional development model of teacher mentoring that is meaningful and facilitates teacher change. In essence, the idea of mentoring is a sound theory, and its use in programs has potential (MacDonald, Silvernail, & Bruccoli, 2002). Unfortunately, the practice of peer mentoring is not commonplace in K-12 environments. Requiring mentoring without a model or vignettes of effectiveness is similar to requiring construction workers to erect a bridge without blueprints or examples of sound bridges.

This dissertation hopes to provide initial blueprints for teacher interactions that may shape future teacher science research programs and inform innovative teachers involved in collaborating/mentoring as professional development. For example, vignettes of meaningful interactions among teachers empirically ground a proposed theoretical model of professional development. This model derived from this research could be applied broadly to teacher science research programs with a mentoring component to test how well the theory correlates with practice and effectiveness. The model may also provide a framework for teachers entry into professional development. Additionally, it may help the educational field better understand meaningful interactions between teachers as professional development resolving problems of practice.

Research Questions

The purpose of this study was to understand mentoring between teachers as professional development that resulted in teacher change. The research questions that guided this study are:

1. How do meaningful interactions among teachers occur?
2. How do teachers describe professional collaborations associated with authentic science research experiences?
3. What elements of interactions among teachers are meaningful?
4. Why are these elements of interactions meaningful to teachers?

The participants of this study were three teachers directly involved in a National Science Foundation (NSF) professional development program and 12 teachers indirectly involved with the program. The study examines incidents of professional development engagements that resulted in reports of teacher change. The next chapter describes the details of the NSF program and an overview of literature related to the professional development of teachers. Chapter 3 provides the methods that guided this study with details about the participants, data collection, and data analysis. Chapter 4 reveals the results of the data analysis using vignettes, findings, and the emergence of a professional development model of teacher mentoring. The final chapter situates the results of this study in the research literature and discusses the implications this study has on professional development of teachers, policy, and science education research. Chapter 5 concludes with suggestions for future research.

Chapter 2

Context

Teachers Experiencing Antarctica and the Arctic (TEA)

The National Science Foundation (NSF) funds many projects that allow K-12 teachers to participate in scientific research. One such program, Teachers Experiencing the Antarctic and Arctic (TEA), sent teachers to Polar Regions with research teams awarded funding from the Office of Polar Programs (OPP). In addition to being viable members of research teams, the teachers were required to conduct educational outreach.

The educational outreach consisted of participants in the TEA program being asked to mentor three colleagues, i.e. protégés, each for a minimum of 137 hours total before, during, and after the field experience within in a three-year period. The NSF used a model of mentoring for the TEA program based on the following criteria: (a) the mentoring must be face-to-face that facilitates the development of content knowledge and teaching/facilitating practices; (b) the mentoring should be an immersion into the polar research experience for the TEAs colleagues (Appendix A). Although other NSF programs require mentoring, the mentoring required in TEA is of specific interest because the NSF used it subsequently as a model to inform their other teacher professional development initiatives.

The founder of the TEA program, Dr. Wayne Sukow (NSF – Program Manager) created the programs' mentoring requirement as a means to better justify the investment

of sending a single teacher into the field. Dr. Sukow sough to increase the dissemination of polar science research into more classrooms using TEAs as mentors to other teachers (W. Sukow, personal communication, 2001). In addition to broadening the impact of the TEA program, the mentoring requirement provides professional development for TEAs and their protégés designed to establish a community of educators with specific content knowledge related to polar sciences.

When the mentoring requirement was incorporated into the TEA program, participating teachers met it with resistance and confusion. The reaction of teachers surprised Dr. Sukow who believed the mentoring requirement would be the easiest component of TEA obligations to fulfill. The reason for the contrasting views of the mentoring requirement may relate to culture. Dr. Sukow has a background in academia, where interactions with colleagues are more commonplace – e.g., coauthoring journal articles. Yet, the teachers required to do the mentoring, and those mentored, work in a less enabling environment, one in which teachers frequently work in isolation. Also, the financial incentive for fulfilling the mentoring requirement was minimal. A stipend of $1000 was awarded to TEAs who completed the required hours of mentoring. No formal incentive (e.g., stipend or graduate credit) was offered to protégés for their involvement.

In an effort to facilitate the mentoring requirement, the TEA program staff instituted Mentoring Resource Groups (MRGs) one year after the 2000-2001 TEA cohort commenced their involvement with the program. An MRG involved small support groups of TEAs meeting via teleconference every other month to discuss strategies for overcoming mentoring difficulties and sharing successes. A member of the TEA

program facilitated these teleconferences. Despite these efforts, the mentoring component of the TEA program was still ambiguous and frustrating to those involved.

The ambiguity and frustration that resulted from using the NSF's criteria for mentoring forms the focus of this research. The NSF's goal of extending the benefits of an authentic research experience to a wider audience may not be realized (MacDonald, Silvernail, & Bruccoli, 2002). Furthermore, the involved teachers may not have benefited from the mentoring model utilized in the program. As the model of mentoring from the TEA program is presently informing other NSF teacher enrichment programs, it is important to research mentoring in this context further so an ineffective model of mentoring does not propagate into future programs. This propagation is evident in an NSF teacher enrichment program recruitment brochure for the 2006 ARMADA project:

> "*ARMADA Master Teachers serve as mentors to colleagues in the home school districts who are new to teaching science. During the two academic years following their research experience, ARMADA Master Teachers and Mentees work together to integrate the research experience into the classroom and identify related standards-based resources and curricula."*

Teacher enrichment programs offered by the NSF have unique advantages over traditional professional development efforts. These programs afford teachers a rare opportunity to participate in scientific research and increase their understanding of natural phenomena (Dresner & Starvel, 2004). Further, teachers in these programs have the potential to enrich colleagues professionally who cannot, or have no desire to, engage in field research – i.e., because of professional or personal constraints. Peer mentoring can broaden the educational impact of NSF initiatives and improve the professional

development of teachers. Teachers from the TEA program were involved in a pilot study that provided a foundation for better understanding teacher-to-teacher mentoring.

Pilot Study

The current study was informed by the results of a pilot study that gathered data relevant to teacher-to-teacher mentoring related to the Teachers Experiencing Antarctica and the Arctic (TEA) program. A survey was sent to TEA program participants eliciting information related to mentoring and their experiences with fulfilling mentoring obligations. For instance, participants provided information such as their age, mentored teachers' ages, physical location of mentored teachers, types of mentoring (i.e., face-to-face), number of mentoring hours completed to date, and frequency of mentoring (e.g., weekly). The research question guiding the pilot study was what themes or categories emerge from the participants' surveys that can produce continua related to successful and unsuccessful mentoring practices.

Surveys were returned by 20 TEAs and revealed that 80% of the participants disagreed that the number of mentoring hours required by the National Science Foundation (NSF) were appropriate. A majority of the participants expected to fulfill their mentoring requirement (i.e., 65 %). Three-quarters of the participants agreed that the mentoring experience had been valuable. This pilot study allowed TEAs to be grouped into categories based on the fulfillment of the NSF mentoring requirement and whether the TEAs found the experience of value.

Introduction

One word that painfully depicts the teaching profession is isolation. The classic ethnography, The Schoolteacher (Lortie, 1975), offers a rich description of the ethos of schoolteachers in which the theme of isolation dominates. Even the professional development of teachers is often a private enterprise because schools fail to provide opportunities to build professional relationships (Loucks-Horsley & Matsumoto, 1999). Mentoring facilitates interactions between teachers and this form of professional development may reduce isolation as reported in chapter 4.

The manifestation of isolation in school culture is important to this study because I am influenced by constructivism as a theory of learning. The origins of constructivism, a cognitive theory positing that knowledge is subjectively constructed, dates back to the eighteenth century (Van Glaserfeld, 1998) and became more prominent as a result of the work of Jean Piaget and Lev Vygotsky (Fosnot, 1996). Van Glaserfeld defines knowledge as, "…conceptual structures that epistemic agents, given the range of present experience within their tradition of thought and language, consider viable." (p. 119). The term viable suggests that knowledge is an adaptive function, analogous to Darwin's view of biological evolution.

Many researchers and philosophers equate theories of cognition to the theory of evolution. For instance, Van Glaserfeld (1998) offers, "[I]n both the theory of evolution and the constructivist theory of knowing, 'viability' is tied to the concept of equilibrium." (p. 120). In cognition, a learner's cognitive structures are in equilibrium when they offer

expected results without any dissatisfaction. Thus, for new learning to occur, there must be dissatisfaction with a priori knowledge.

Mentoring is one form of professional development facilitating the acquisition of knowledge. The literature on peer mentoring between teachers is limited. Nonetheless, integrating the available literature with my pilot study offers a starting point for understanding mentoring as related to the TEA program and beyond.

This chapter lays out three benefits of mentoring that emerged from the literature: (a) reducing isolation through collaboration, (b) changing teachers' practices, and (c) facilitating teacher learning. In addition to mentoring, other models of professional development of science teachers are related to this study. Included within this chapter are arguments for professional development, particularly in the form of research experiences for science teachers. The final section reinforces the main points of each section of this chapter and how those points inform this study.

Mentoring

The majority of research on teacher mentoring defines quality mentoring between pre-service and in-service teachers and highlights strategies that facilitate successful mentoring experiences. Administrative support is critical for successful mentoring experiences between pre-service and in-service teachers (Smoot, 2000). In this case, the administrator acts as a catalyst for making the mentoring experience meaningful. It should be noted that this type of mentoring is often for the socialization of the new teacher into the school culture, rather than changing a practicing teacher's practice.

Additional research of mentoring between pre-service and in-service teachers reveals the importance of comfort level with mentoring (Brimijoin & Alouf, 2003). My pilot study on mentors from the TEA program revealed through surveys that 80% of the TEA respondents (n = 20) were comfortable with the mentoring process. However, the comfort level with mentoring does not indicate it was a meaningful professional development experience (Loucks-Horsley and Matsumoto, 1999).

A second factor that influences the quality of a mentoring experience is the quality of the mentor. Mullinix (2002) found that the most influential criterion for selection of mentors is their reputation as effective classroom teachers. Mentoring is in itself rewarding: Mullinix indicated that experienced teachers involved in mentoring receive, "improved professional competency, reflective practice, professional renewal, psychological benefits (enhanced self-esteem), collaboration and collegiality, contributions to teacher leadership, and pedagogical inquiry/teacher research." (p. 3).

The use of mentoring often suggests a hierarchy. The mentor possesses knowledge that the protégée wishes to acquire (Peper, 1994). This relationship can be seen between classroom teacher and student, coach and athletes, and journeyman and apprentice. However, this interpretation has the potential to cause conflict because a hierarchy between in-service teachers is not an established part of teachers' culture. The only exception is the relationship between seasoned teachers and new teachers. How then, does mentoring occur between *seasoned teachers* – teachers defined herein as having five or more years of experience in the classroom?

Initial research into this question reinforces the unease teachers have with mentoring peers. For example, teachers interviewed about their mentoring experience

with the TEA program express discomfort with mentoring their colleagues – not only with the term but also the process; they prefer to view their efforts as collaborations. Nonetheless, many contemporary science teacher professional development efforts contain mentoring requirements. To make these efforts fruitful and amplify the investment of the funding agencies (e.g. National Science Foundation) a better understanding of seasoned teacher-to-teacher mentoring is necessary.

The use of the word mentor in professional development reforms works well when seasoned teachers are paired with beginning teachers. As previously stated, seasoned teachers are uncomfortable with the term mentor when paired with other seasoned teachers. Peper (1994) offers, "[o]ne problem with the word may be that it is a convenient label for any of the complex activities we associate with teaching or coaching of professionals." (p. 2). Circumventing this unease may be as simple as using different nomenclature, such as teacher collaborations or teacher interactions. Van Driel et al. (2001) highlight professional development reforms using strategies based on learning networks and peer coaching. Both strategies can be interpreted as mentoring efforts that reduce the isolation of teachers and promote change in classroom practice.

Reducing Isolation through Collaboration

Collaborations between teacher peers, as well as between teachers and university faculty, that promote teacher learning have promise (Constible et al, 2007). However, collaboration alone does not necessarily facilitate professional development, for a catalyst (e.g., enacting new curriculum) is necessary for the effort to be meaningful (Marshall,

2005). Collaboration between TEAs may be considered professional development, with the research experience and the transfer of that experience to classroom acting as the unifying factor. Yet, what catalyst exists for the protégés of TEAs?

One possible catalyst is a dialectic model of professional development between teachers and researchers that comprises collaboration, enactment and reflection (Blumenfeld et al., 1994). From this perspective, the TEA would be considered the authority figure. Their model of collaboration succeeded in transforming teachers' beliefs and practices from being transmitters of knowledge to an approach more aligned with constructivism. Yet, Blumenfeld et al. concede, "[t]he process [of transforming teachers' beliefs and practices] is time consuming, labor intensive, and expensive." (p. 547). Furthermore, the model described by Blumenfeld et al (1994) requires collaborations that must include researchers because the goal of the teacher change is directed toward adherence to a theoretical framework – i.e., transitioning from behaviorism to constructivism. Such a change is unlikely without the expertise of a teacher educator who is more knowledgeable in theory than a teacher whose knowledge is more grounded in classroom practice.

Face-to-face collaborations between researchers and teachers are often difficult to establish because of spatial and temporal constraints. However, collaborative efforts are more easily facilitated between administrators and teachers because they usually work in the same building and work together to fulfill federal mandates. Such support for collaboration can be elicited from principals, and high-stakes testing can be the catalyst for collaboration (Marshall, 2005). Using the common saying 'nothing unites people more than a common enemy', high-stake tests can be the unifying force for teacher

collaborations if principals are willing to encourage such efforts. High-stakes testing is mentioned because 80% of TEAs surveyed during the pilot study that did not fulfill their mentoring obligation stated it was due to administrative pressure related to such tests.

High-Stakes testing is a result of The No Child Left Behind (NCLB) Act of 2001. NCLB also mandates that states ensure the availability of "high-quality" professional development for all teachers. Yet, past and present professional development endeavors do not fulfill the intentions of NCLB (Borko, 2004). Borko summarizes educational researchers' current understanding of professional development as a system containing four key elements: professional development programs, teachers, facilitators, and the context in which the programs occur.

Viewing the mentoring requirement of the TEA program using these elements reveals that one element is missing. The mentoring itself may be considered the program; the TEAs and protégés are the teachers; and the research experience and classroom transfer are the context. Who are the facilitators? The interrelationship between these elements of this model is what makes understanding professional development collaborations so complex.

One type of teacher collaboration appearing in literature is community of learners. Community of learners is defined as a group of people coming together for in depth exploration of challenging subject matter (Thomas, Wineburg, Grossman, Myhre, & Woolworth, 1998). Thomas et al. (1998) implemented a professional development program with a community of learners involved in bi-monthly meetings. The foci of the collaboration were discussions centered on book readings. This approach for developing a community of learners is intriguing, for it reportedly reduced teacher isolation, but there

is little evidence offered to suggest changes occurred in teachers' practices. Changing teacher practice is discussed in the next section. Communities of learners that do report changes in teachers' practices often involve partnerships between school and university personnel – e.g., Professional Development Schools (Dana et al., 2001) and Earth-View (Dawkins and Dickerson, 2007). However, as previously mentioned, relationships between public school teachers and university faculty are limited and not available to all teachers.

Professional Development of Science Teachers

Researchers at the University of Michigan have provided a great deal of understanding about professional development related to science education (Blumenfeld et al., 1994, Marx, Freeman, Krajcik, & Blumenfeld, 1998). The contemporary research approaches by these authors are anchored in constructivism. Marx et al. (1998) reflect this stance by suggesting, "…teachers construct their knowledge by integrating new learning with prior knowledge and beliefs, by applying ideas to practice, and by reflecting on the results." (p. 669). Although constructivism has many facets, social constructivism resonates from the work of Marx et al., "…teachers construct their knowledge through social interactions with peers…" (p. 670). Thus learning may be viewed as an individual effort mediated by social interactions. This framework provides argument for professional development efforts utilizing the project-based instruction discussed by Blumenfeld et al. and Marx et al. Given the empirical evidence supporting

constructivism as a theory of learning, future professional development models would benefit from using constructivism as a theoretical framework (Tobin & Tippins, 1993).

One central goal of many professional development efforts is the improvement of student achievement. This is one reason that the NSF enacted a mentoring requirement; so that more students are exposed to the efforts of principal investigators (McDonald et al (2002). Supovitz & Turner (2001) verified a relationship between changed teaching practices as a result of professional development and student achievement – particularly in science. This relationship does not imply that certain teaching practices foster student achievement better than others. Rather, it demonstrates a need for additional research exploring how professional development efforts change teaching practices, which could result in higher student achievement.

Supovitz and Turner (2000) explored one component of a model showing the relationship between professional development and student achievement: the relationship between high quality professional development and educators' use of inquiry-based teaching practices. The authors categorize professional development as *high* quality when most of listed components are met:

1. *model inquiry forms of teaching*
2. *remain intensive and sustained*
3. *engage teachers in concrete teaching tasks and be based on teachers' experiences with students*
4. *focus on subject-matter content and deepen teachers' content skills*
5. *relate to a common set of professional development standards*
6. *connect to other aspects of school change*

It was found that teachers who engage in high quality professional development were able to change their teaching practices.

The degree of professional development necessary for instructional practice change to occur underlies the impact of professional development efforts and change to teaching practice in the classroom. Excluding analysis of the traditionally fragmented and top-down approaches (Van Driel, Beijaard, & Verloop, 2001) to professional development found in schools, which often are restricted to predetermined and fragmented in-service days, some efforts have specific time requirements that extend well beyond a few days. The National Science Foundation's Teachers Experiencing Antarctica and the Arctic (TEA) engaged teachers in inquiry-based professional development for 137 hours over a three-year period. Another intensive professional development program required teacher participation of 160-190 hours over three years (Supovitz & Turner, 2000). However, is this much engagement and commitment necessary for a significant change in teacher practice? After all, the number of required hours for mentoring was the largest complaint among TEAs. Of the TEAs surveyed, none thought the number of required mentoring hours were appropriate. Emphasizing this further, 45% *strongly* disagreed the hours were appropriate.

Supovitz and Turner (2000) offer an answer to this question specific to teachers using inquiry-based teaching practices and classroom investigative culture. A classroom investigative culture emerged after 40-79 hours of professional development and use of inquiry-based teaching practices became significant after 80 hours of professional development. But the largest change in the latter did not occur until after 160 hours (Supovitz & Turner, 2000). According to Supovitz and Turner, "[t]he most powerful individual influences on both teaching practices and investigative culture were teachers' content preparation and attitudes towards reform." (p. 974). Therefore, any professional

development effort that is selective (e.g. TEA, ARMADA, and TREC) would benefit from identifying teachers with positive attitudes for reform and offering opportunities to these teachers for increasing content knowledge.

Many educational research efforts concentrate on professional development programs that focus on changing classroom practices and increasing teacher subject matter knowledge (Borko, 2004). One program reporting success, Learning through Inquiry Science and Technology (LIST), sought to change teachers' classroom practices from teacher-centered to learner-centered (Gerber et al., 2003). Another study compared two professional development programs focused on increasing teacher subject knowledge (Crowther & Cannon, 2002).

Crowther and Cannon (2002) found that follow-up workshops are important to professional development, rather than the intensity or duration of specific workshops. Emphasizing this point, they add, "The follow up workshop provided the motivation for the teachers to actually try out different labs and teaching practices so that they would have something to report to the rest of the group." (Crowther & Cannon, 2002, p. 14). This observation does not suggest that duration and intensity are not important; especially when consideration is given to the integration of more difficult challenges such as incorporating inquiry into practice.

As stated previously, studies of professional development that incorporate inquiry-based practices and promote investigative classroom culture suggest that in addition to quality, the quantity of professional development hours teachers engage is significant for promoting long-lasting change in a teacher's classroom practice (Supovitz & Turner, 2000).

Arguments for Professional Development

Much attention has been devoted to professional development of pre-service teachers (Smoot, 2000) and new teachers. This attention is warranted because it is generally recognized that a teacher's first few years of service set precedent for the remainder of their career (Hammond-Darling, 1998). However, professional development should not cease once tenure is achieved – a status awarded after three years of teaching deemed satisfactory by teachers' supervisors.

Another argument for aligning to the principles of lifelong learning is the lack of effective new teacher professional development, often referred to as induction programs. Induction programs are a means of indoctrinating new teachers into the profession. In practice, mentor teachers often act as lifeguards, helping new teachers stay afloat, in the *sink or swim* analogy applied to the first year of teaching. Induction programs are thus a form of retention effort, designed to reduce the number of teachers leaving the profession. Teachers who do remain in the profession after tenure are confronted with fragmented professional development (Borko, 2004) and intellectual confinement (Lortie, 1975).

What has emerged from educational scholars as an ethic for education is 'best interests of the students' (Shapiro & Stefkovich, 2001). Rich and meaningful professional development of teachers is in the best interests of students. Since the average teaching career spans decades, quality professional development must be lifelong. Even contemporary professional development models, such as project-based

science, take at least three years of continual engagement (Marx, Blumenfeld et al., 1998).

What is in the best interests of the students also encourages thought about the reason for reform in science education. Van Driel et al. (2001) reflect traditional views of science teaching in public schools with, "[s]cience is usually presented as a rigid body of facts, theories, and rules to be memorized and practiced, rather than a way of knowing about natural phenomena." (p. 138). This approach may have been appropriate when behaviorism was the dominant theory of learning and the nation's science education efforts blossomed following the science fever induced by the space race. However, this method of teaching science has proven antiquated in the context of contemporary learning theory, such as constructivism, and many efforts to change this situation have been introduced nation-wide (AAAS 1989, 1993; National Research Council, 1996).

Research Experiences for Teachers

Few teachers have scientific research experience affording them insight about the nature of science. Teachers who have had prior scientific research experiences are more likely to incorporate inquiry activities in their classrooms (Windschitl, 2004). Thus, teachers who have science research experience may be a resource for other teachers attempting to incorporate science inquiry practices into their classroom.

The realization that research experiences are an important ingredient for the successful implementation of inquiry practices in the classroom offers support to funding agencies promoting such efforts (Wenglinsky & Silverstein, 2007). For example, the

National Science Foundation (NSF) funded the Teachers Experiencing Antarctica and Arctic (TEA) program for over a decade. The TEA program sent teachers to the Polar Regions as viable members of a research team. There is little argument that the teachers involved in this program had a unique opportunity to learn about scientific inquiry. Yet, the experiences do not offer a framework for transferring that new knowledge to other teachers and the classroom (R. Putnam & Borko, 2000). Additionally, efforts such as TEA are restricted to a limited number of participants due to financial and logistical constraints.

Professional development grounded in constructivism facilitates teachers learning new practices (Davis, 2003). Given that knowledge is socially constructed, it is crucial that new learning occur in communities of practice. Davis reinforces this notion and also emphasizes the importance of extracting teachers' a priori knowledge and beliefs. Also, since knowledge is situated, it is important that professional development efforts occur within context, i.e., schools and classroom settings (Putnam & Borko, 2000).

Since teachers do not normally possess a strong theoretical understanding of constructivism, support from research and professional development teams is necessary (Davis, 2003). Hence, collaboration between teachers and researchers may offer the best solution to successfully changing teachers' practices (Putnam & Borko, 2000). Again, however, there are a limited number of research and/or professional development staff available for such a commitment (Putnam & Borko, 1996). The realistic approach is to generate a model of professional development that can be utilized by collaborations of teachers.

Currently, there are a wide variety of professional development offerings for teachers. In many cases, the selection of these learning opportunities is left in the hands of the teachers. The types that I find particularly interesting are selective programs that provide teachers opportunities to engage in authentic science research experiences. Examples of such programs are: (a) the TEA program previously mentioned, (b) REVEL; a program that sends teachers to study deep-sea vents off the coast of Washington, and (c) ARMADA; a program pairing teachers with researchers aboard an ocean research vessel. Each of these programs provides teachers fantastic opportunities to increase their content knowledge and become indoctrinated in the culture of science.

One commonality between all of these programs is they each have a mentoring component. Teachers involved in the research experiences are expected to transfer and translate that experience with other teachers and create meaningful opportunities for changing teachers' practices to better align with science inquiry. Yet, none of the funding agencies for these programs offer a framework for fulfilling this goal. Putnam and Borko (1996) offer a potential solution, "…professional development experiences, *situated* in a variety of contexts, are potentially valuable tools for helping teachers to change their instructional knowledge, beliefs, and practices." (p. 1260). For example, increasing a teacher's content knowledge may be best accomplished outside the classroom – perhaps situated in an authentic research experience. But how does the professional development experience of one teacher transform to meaningful professional development for other teachers resulting in teacher change?

Conclusion

The TEA program and other similar teacher enrichment opportunities offer a unique avenue for professional development. Furthermore, such programs may act as a catalyst for collaborations between seasoned teachers. The literature informing this study reveal: (1) teaching is an isolated profession, (2) typical modes of professional development often fail to facilitate teacher learning and change in classroom practices, and (3) understanding meaningful teacher interactions may offer a solution. This study uses naturalistic inquiry to explore interactions among teachers in the context of a science research experience program.

Chapter 3

Methods

In this chapter I will describe the design of this study. I begin with an overview of grounded theory and how this theory informed data collection and analysis. Next, I discuss the role of the researcher and the study's limitations. The questions that guide this study are:

1. How do meaningful interactions among teachers occur?
2. How do teachers describe professional collaborations associated with authentic science research experiences?
3. What elements of interactions among teachers are meaningful?
4. Why are these elements of interactions meaningful to teachers?

Introduction

The culture of teachers resides in a complex social environment. Such complex social environments contain numerous variables that complicate making sense of investigations into educational issues. Currently, there are a variety of educational research methods that can be used to guide a study (Fraenkel & Wallen, 1996). Because educational contexts are complicated (NRC, 2003) they are best understood in situ (Strauss and Corbin, 1998). Thus, a naturalistic inquiry approach is adopted for this

study. Grounded theory is the analytical approach used in this study within the context of naturalistic inquiry.

Naturalistic inquiry contrasts with true experimental research. Unlike a controlled laboratory setting, naturalistic inquiry is a dynamic process that occurs in real-world conditions. All of the necessary data for a naturalistic inquiry are not decided upon at the onset (Patton, 2002). Instead, the data emerge throughout the study as new understanding develops. Naturalistic inquiry is thus a discovery-oriented approach to understanding phenomena.

Grounded Theory

Since education is a human endeavor, educational researchers have adapted qualitative research methods, which place an emphasis on words, from other disciplines (Maxwell, 1996). One tradition, ethnography, was borrowed from anthropology (Cresswell, 1998). Ethnography is the documentation of the everyday experiences of individuals over an extended period of time in a naturalistic setting. A seminal example of ethnography is Dan Lortie's, *Schoolteacher: A Sociological Study* (1975), which demonstrates how understanding can be derived from complex social environments.

Another research tradition capable of extracting understanding from educational settings is grounded theory, which was adopted from sociology. Sociologists Barney Glaser and Anselm Strauss are credited with proposing grounded theory as a qualitative research method. Glaser and Stauss (1999) define grounded theory as, "…the discovery of theory from data…" (p. 1). This theory contrasts with other traditions of research,

both quantitative and qualitative, by subduing the emphasis of logical deductions from a priori assumptions (Patton, 2002). Traditional research perspectives tend to stress the verification of theories. The focus of grounded theory is the generation of theory.

Grounded theory is not limited to qualitative data, but it has appeal to qualitative researchers because of the specific procedures for generating theory. Patton (2002) adds, "…grounded theory is best understood as fundamentally realist and objectivist in orientation, emphasizing disciplined and procedural ways of getting the researcher's biases out of the way but adding healthy dose of creativity to the analytic process." (p. 128-129). Within this methodological framework, I used comparative analysis of interview transcriptions from TEAs and their protégés. This approach provides a foundation for generating a substantive theory regarding mentoring as professional development. Below I will highlight specific procedures aligned to grounded theory that informed this study related to the professional development of teachers.

Data Collection

The process of collecting data that are used to generate theory is termed theoretical sampling. Theoretical sampling involves the simultaneous collection, coding, and analysis of data. In this nonlinear approach one of the goals of interim analysis is an indication of what data to collect next. However, using data to inform further data collection requires careful collection of initial data. Pilot data for this study were obtained from a survey distributed to TEAs in 2004. The pilot study sought to learn if age differences between mentors and protégés correlated with completion of the

mentoring requirement of the TEA program. The study revealed that age differences and completion of the required mentoring hours were not related, but it did allow for the establishment of comparison groups comprising those that completed the requirement and those that did not.

Defining comparison groups cannot be established rigidly at the onset of a research study. Glaser and Stauss (1999) elaborate with, "[i]n research carried out for discovering theory, the sociologist cannot cite the number and types of groups from which he collected data *until* the research is completed." (p. 50). Thus, selecting groups at the onset of a study requires recognition that they are artifacts of the research design.

The pilot study involved 20 TEAs completing a survey (Appendix B) comprising basic background information, protégé information, ranked responses, and open-ended questions. Preliminary analysis of the data revealed divergent attitudes about participants' expectations for completing the mentoring requirements.

TEAs expecting to complete their mentoring obligation were more likely to agree with their comfort, understanding, and training as a mentor. In contrast, TEAs indicating they did not expect to fulfill their mentoring obligation averaged neutral responses to the same questions about mentoring. The only commonality between the two divergent groups was their agreement that the required number of mentoring hours was inappropriate.

The open-ended questions revealed additional understanding about the mentoring process that occurred via the TEA program. When participants responded to a question about the greatest challenge of mentoring their answers centered on logistics and protégé motivation. Surprisingly, none of the respondents shared concerns about the quality of

the mentoring or how meaningful the mentoring was to the protégés. This suggests an emphasis on the mechanics of mentoring. Therefore, additional data were necessary to allow for a description of the meaningful interactions to be synthesized.

To facilitate additional data acquisition, TEAs who participated in the pilot study were asked to invite their protégés to complete a brief online survey (Appendix C). The survey allowed access to protégés if they agreed to a follow-up telephone interview; follow-up interviews were conducted with 12 of the 18 protégés who completed the online survey. The 12 protégés who agreed to an interview were contacted via e-mail to coordinate a date and time to call.

Each interview followed a format comprising a warm-up question, elaborations on survey responses, and descriptions of teacher interactions. A more rigid interview format was not followed so interviewees could better describe their experiences freely without leading questions. An example of a warm-up question from an interview is, "Would you describe the research that your TEA participated in during their field experience?" Examples of other questions from the interviews are:

> *In response to the question, 'What did you anticipate to gain from the interaction?' you checked 'other'. What specifically did you anticipate to gain that would help you become a better teacher?*
>
> *Can you describe what a person would see if they observed one of your mentoring sessions?*

Each interview was taped and transcribed within 24 hours. Then, the transcript was read and memos recorded.

The pilot study group comprised TEA teachers. Within this category are two subsets: TEAs who fulfilled their mentoring requirements and those who did not. Fulfillment of the mentoring requirement can be viewed through the eyes of the NSF – teachers who met the NSF's criteria for mentoring, and through the eyes of the TEAs – teachers who concluded personally they had success with mentoring. Placing teachers in a two-dimensional grid using data from the pilot study survey and follow-up interviews revealed initial comparison groups (**Figure 3-1**) and TEAs to interview. Capital letters denote effectiveness as defined by the NSF's model of mentoring. Lower case letters indicate teachers' personal views of effective mentoring. Since the focus of this study is to understand meaningful interactions, the only TEAs with whom interviews were requested were from were those in the top row of Figure 3-1. Five TEAs were invited to participate in an interview and three agreed. Two TEAs did not respond to the request to participate in an interview.

EFFECTIVE

NSF		
	YES yes	NO yes
	YES no	NO no

Teacher

Figure 3-1: TEA Comparison groups.

This grid classifies TEAs as effective mentors based on criteria from the National Science Foundation (capital letters) and teachers (lower case letters). TEAs that fulfilled both criteria were invited to participate in this study.

Achieving theoretical saturation can be very time consuming. In fact, many qualitative research studies are time intensive (Cresswell, 1998). One cause for the length of time required to complete a qualitative study is obtaining data from people who are to be observed or interviewed (Glaser & Strauss, 1999). Without an already established rapport, time may be spent earning trust and gaining access to a group. One

researcher argues that a minimum of one year in the field is necessary for establishing rapport and collecting data (J. LeTendra, personal communication, 2004). Fortunately, obtaining data from TEAs was facilitated by my inclusion within this group which facilitated with establishing rapport.

Data Analysis

The use of grounded theory to inform a research study requires a systematic process of data analysis. A standard format found in many grounded theory studies comprises three coding types: open coding, axial coding, and selective coding (Cresswell, 1998). The premise behind open coding is the discovery of concepts, which are the building blocks of theory (Strauss & Corbin, 1998). The open coding process involves breaking data down into incidents and conceptualizing them with representative names. A portion of an interview is shown to exemplify the open coding process:

> Interviewer: *You indicated that you would be willing to participate in a similar program in the future. If such a program came up what would you hope to get out of it now that you have gone through one already?*
>
> Respondent: *Probably similar results. I would hope, selfishly for myself, it would be another area that didn't have a huge amount of background in* [teacher change]. *Another branch of science* [content knowledge] *or area of the world that I didn't know as much about. So, it would be learning experience* [teacher change] *for me along with my students* [student achievement].
>
> Interviewer: *Would you specifically look for something outside your area of expertise?*
>
> Respondent: *Yeah, I think so.*
>
> Interviewer: *Why do you think that is important?*

> Respondent: *I think it is fun* [fun – in vivo code] *to learn new things* [teacher change]. *I also think the more I know related to science* [content knowledge] *the more effective* [teacher change] *I am in the classroom* [student achievement].

The term coding refers to the action of data analysis. Initial data analysis resulted in a list of level 1 codes that conceptualize portions of the interviews with representative names. These level 1 codes also included in vivo representations. The open coding process resulted in a list of numerous level 1 codes. Multiple dimensions can describe a level 1 code. For example, the level 1 code *resources* can be described by physical items or virtual items (e.g., Internet websites). Eventually, the list was reduced to twelve level 1 codes (Table 3-1). These level 1 codes provided a basis for the discovery of categories that reflect relationships among the level 1 codes. Categories are higher-level concepts that provide more abstraction from the data than level 1 codes. Each category is characterized by its properties that define and give the category meaning. Level 1 codes are empirical whereas properties and categories are abstract and more theoretical (Table 3-2).

Table 3-1: Level 1 Codes and descriptions

Content Knowledge	Content knowledge is specific to a teacher's subject area. This knowledge refers to concepts and information related to scientific understanding of natural phenomena. (e.g., physics)
Pedagogical Content Knowledge	Pedagogical content knowledge refers to understanding effective methods of teaching particular subject matter to students of diverse abilities and cognitive levels. (e.g., science inquiry)
Resources	Resources are materials that teachers can use in their classrooms to compliment instruction. These are physical items that teachers can add to their classroom inventory. (e.g., extreme weather gear)
Vicarious Experience	Vicarious experiences are descriptions of experiences shared by others working or traveling in unique or exotic locations. These are second-hand accounts. (e.g., fieldwork on the Ross Ice Shelf)
Curriculum	Curriculum describes what is planned for or implemented in the classroom. It may be individual lessons, activities, or units. (e.g., marine science course development)
View Point	View point refers to the value placed on participants' ideas during interactions. Interactions may have a single 'correct' view point or multiple 'correct' view points. (e.g., valuing the opinions of others)
Access	Access describes the degree of ease teachers have initiating further interactions with those involved in an initial interactions. (e.g., contacting a presenter after a program for follow-up questions)
Focus	Focus describes the intent or purpose of an interaction. Focus falls on a continuum between information dissemination and synthesis. (e.g., develop science inquiry classroom activities)
Transfer	Transfer is the extent that an interaction carries beyond the initial engagement. This may include a teacher's use of ideas in their classroom or professional development. (e.g., use of lesson plan)
Ownership	Ownership describes a participant's role as a stakeholder in the success of an interaction or engagement. (e.g., a teacher co-developing a presentation for a science teacher convention)
Enthusiasm	Enthusiasm refers to descriptions of teachers' personal views of their enjoyment toward teaching. The descriptions also apply toward teachers describing others. (e.g., I felt recharged)
Perspective	Perspective describes how teachers view other people and themselves. Perspective may describe conceptions of people's abilities and careers. (e.g., students ability to analyze data)

Table 3-2: Summary of Level 1 Codes, Properties, and Categories

Category	**Property**	**Level 1Codes**
Action	Dissemination	Content Knowledge Pedagogical Content Knowledge Resources
	Acquisition	Content Knowledge Pedagogical Content Knowledge Resources Vicarious Experiences
	Synthesis	Content Knowledge Pedagogical Content Knowledge Resources Curriculum
Interaction	Authoritative	View Point Access Focus Transfer Ownership
	Dialogic	View Points Access Focus Transfer Ownership
Engagement Result	Teacher Change	Content Knowledge Pedagogical Content Knowledge Enthusiasm Perspective

Generation of Theory

The generation of theory begins with the substantive-level theory, i.e., theory that is directly related to the data. Cresswell (1998) suggests that following the above-mentioned format will result in a substantive-level theory. A substantive theory is appropriate, in contrast to a formal theory, because the goal is to generate theory specific to science teachers working in elementary and secondary classrooms. A formal theory, often developed after a substantive theory, can be generalized across a broader arena.

The constant comparative method of data analysis was used to develop three categories that describe incidents of teacher-to-teacher mentoring: action, interaction, and result. There are four stages to the constant comparative method (Glaser & Strauss, 1999):

1. *Comparing incidents applicable to each category*
2. *Integrating categories and their properties*
3. *Delimiting the theory*
4. *Writing the theory*

These stages are not strictly linear, but rather operate continually until all analysis is completed.

The first stage, comparing incidents applicable to each category, involves coding data into categories. Glaser and Strauss (1999) suggest, "while coding an incident for a category, compare it with the previous incidents in the same and different groups coded in the same category." (p. 106). This suggestion resulted in comparing an incident for a category between protégés and also between protégés and TEAs.

After coding a category numerous times, it was necessary to reflect on personal ideas (e.g., Appendix D). Personal ideas fluctuated greatly during the analysis process. This interview segment reveals an example of the reflective process:

> Interviewer: *Have you had similar interactions with your peers now that the program is over?*
>
> Respondent: *Now I am more knowledgeable in the area so I am comfortable* [Comfort talking about a subject she previously knew less about. Is this demonstrating teacher change?] *talking with them about their field versus mine. Maybe the question was more did it break down boundaries*. [Break down boundaries (in vivo code). As a result of her participation in this program, her interactions and the focus of the interactions have changed]*, am I…do I feel I can interact with them more.*

Any arising theoretical notions should be grounded in the data and not speculative in nature (Glaser & Strauss, 1999). After returning to the data for additional coding and constant comparison, the second stage can be initiated.

The second stage, integrating categories and their properties, is a process Glaser and Strauss (1999) elaborate upon by stating, "the constant comparative units change from comparison of incident with incident to comparison of incident with properties of the category that resulted from initial comparisons of incidents." (p. 108). For example, comparing incidents of the category action revealed that teachers described changes to their content knowledge. Comparing incidents of content knowledge revealed the property synthesis. Analyses of incidents influencing content knowledge were compared with incidents of content knowledge synthesis. This analysis revealed that the synthesis of content knowledge was related to the meaning or value a teacher described during an action that transformed practice and increased subject matter knowledge.

Delimiting the theory is the third stage of the constant comparative method of qualitative analysis. Simply stated, this stage involves reducing the number of categories, thus allowing for the formulation of a theory with fewer higher-level concepts (Glaser & Strauss, 1999). This reduction allows the theory to be generalized so that it applies to the professional development of all science teachers involved in authentic research experiences – not just those involved in the TEA program.

The final stage of the constant comparative method is writing theory. Glaser and Strauss (1999) suggest that this stage can be started, "[w]hen the researcher is convinced that his analytic framework forms a systematic substantive theory, that is a reasonably accurate statement of the matters studied, and that it is couched in a form that others going into the same field could use – then he can publish his results with confidence." (p. 113). The result is a theory that can be generalized beyond the qualitative data used to discover the theory.

Substantive Theory

The categories that emerged from the protégé and TEA interviews that represent teacher-to-teacher mentoring were shared with practicing teachers to ensure that analysis was grounded in the data and reflective of schoolteachers' culture. The categories that represent teacher-to-teacher mentoring are *action*, *interaction,* and *engagement results*. Each interview was reviewed to identify exemplifiers of each category that are representative of all participants. The exemplifier interviews were then abridged to construct vignettes that highlight each category. Collectively, the vignettes provide a

chain of evidence between the data and theory. These vignettes demonstrate the perspectives of two protégés and their TEA and reveal the discovery of a professional development model that accurately describes meaningful teacher-to-teacher mentoring. The use of mentoring in this study refers to mentoring between teachers, rather than the mentoring of a teacher, i.e., there is mutual benefit for each participant. The number of participants available for this study does not allow saturation to be reached. Thus, the approach to data analysis adapted from grounded theory makes it is impossible to present a substantive level theory. The theory revealed in this study can be generalized beyond the TEA program and future research may attain saturation and the discovery of substantive level theory.

Role of Researcher

There is a potential for bias in this study due to my involvement in the TEA program. I was selected to participate in the TEA program as a member of the 2001-2002 cohort. My involvement included a six-week field experience to the Amundsen-Scott South Pole Station in Antarctica and face-to-face mentoring of three colleagues from my school district.

I found the mentoring requirement difficult because of unclear instructions as to what qualifies as mentoring and coordinating face-to-face meetings with my protégés. I also felt uncomfortable mentoring teachers with more professional experience than myself. To reduce bias, I elected to not include my protégés in this study.

Another source of bias relates to my involvement in the TEA program as a facilitator of Mentor Resource Groups (MRGs). My role in the MRGs was to facilitate conference calls with groups of TEAs to share successful mentoring efforts and offer support to overcome obstacles interfering with the fulfillment of a TEAs mentoring requirement. My perspectives on the program and approach to understanding mentoring may be influenced by the interactions I had during these conference calls. The last conference calls took place during the fall of 2004 marking the conclusion of the TEA program.

Limitations

There are significant limitations in this study. First, the participants' descriptions were based on events that occurred several years previously. It is possible that important details were forgotten. One can argue that the passage of time between the mentoring and this study reveals only fragments of the experience. Therefore, only meaningful experiences that had long lasting effects may be analyzed.

A second limitation is accessing members of the Teachers Experiencing Antarctica and the Arctic (TEA) program. During the program's existence, over 60 TEAs were required to mentor three other teachers. Assuming each TEA honored the contractual agreement, a minimum of 180 protégés are available. I was only able to locate and interview 12 protégés and 3 TEAs and I did not include my protégés in this study. The findings from this small sample size may not reflect the entire population.

A final limitation on this study relates to teacher change. Since all descriptions are reflective, there is no way to verify if change actually took place. All claims of teacher change are based on teacher's personal perceptions.

Chapter 4

Results and Discussion

Findings

The length of participant interviews ranged from 16 minutes to 42 minutes. The median interview length was 24 minutes. The transcriptions of the 15 interviews totaled 94 pages. Each transcription was single-spaced with a line separating interviewer and interviewee dialogue. Protégé and mentor interview transcriptions totaled 74 and 20 pages respectively. Analysis of these data revealed three categories: action, interaction, and results.

Vignettes representing the interviews from three teachers are used to introduce each category. Since no significant differences were found between TEA mentors and protégé groups, the vignettes are representative of all participants. The vignettes comprise protégé teachers Eleanor Helin and Victoria Bennett and their TEA mentor teacher Rosalind Harding. These vignettes are representative of other interviews conducted during this study. Each vignette was constructed from an individual teacher's interview and includes representations of properties of the category. Properties are the characteristics of a category giving it definition and meaning. Properties are identified in each vignette by bold italic text between parentheses (e.g., (***synthesis***)).

Each vignette is followed by a bar graph that reveals the number of incidents a category appears in the data. The number of incidents refers to the number of times a

category appears in the data. The graphs depict the distribution of level 1 codes for each property of a category. A model is shown after each graph to represent each category in the order they are presented in this chapter. The chapter concludes with a discussion of a professional development model of teacher mentoring comprising all three categories.

Actions

Each incident of teacher-to-teacher mentoring has an action that describes what participants do with information during a professional development engagement. The properties of action are dissemination, acquisition, and synthesis. Dissemination is the act of giving information and acquisition is the act of receiving information. When participants give and receive information to develop new information the act is defined as synthesis.

The first vignette only includes incidents of action marked with codes. Codes representing other categories and their properties do not appear to help emphasize the category action.

Vignette 1 – Eleanor Helin

Eleanor is a high school science teacher who began collaborating after Rosalind returned from her science research experience. Eleanor's motivation for working with Rosalind was based on previous mentoring experiences. Eleanor mentored Rosalind in

Environmental Science and Rosalind mentored Eleanor in Chemistry because each possessed expertise in a content area that the other did not.

The mentoring that occurred as a result of Rosalind's involvement with the Teachers Experiencing Antarctica and Arctic (TEA) program took place through weekly face-to-face meetings. These interactions eventually yielded an idea to develop and implement a teacher workshop. The interactions took place more frequently as the workshop got closer.

Eleanor's ownership in the workshop is evident through the following statements:

> *The three of us planned it, organized it, put it all together and then all three of us were presenters* (***synthesis***). *I presented on inquiry based learning in a high school science classroom* (***dissemination***).
>
> *I have a lot of experience with workshops, in organizing groups of people.*
>
> *One of the teachers brought in this lab that was very cookbook style and we really worked it out and ramped it up to be more inquiry based* (***synthesis***). *I ended up using that in my own classroom.*

Eleanor described the workshop as meaningful and noted that it contrasted with other types of professional development:

> *The reality of your day is four periods lasting an hour and a half each. Then, there is setting up the lab for the next day or grading and what not. Having time to develop new stuff is critical* (***synthesis***). *We have two professional days a year. That just is not adequate because those have to be on a particular school issue. It is a time issue where it was pleasant to have two and a half days to work with other teachers and the scientists simultaneously so we could develop things* (***synthesis***) *that were really meaningful. It is great to go to a conference and then – you want to come home and apply all this stuff. But, the reality is there is not enough time for you to apply what you learned. That was the goal that the three of us had in developing that conference. People would – could have something to take home. That was great.*

As a result of the workshop, Eleanor described several changes:

> *[D]ifferent interactions with the different teachers at the program and seeing some of the things that they do and – especially in different class areas helped broaden my range of knowledge* (***acquisition***). *What I cover and how things are covered in the different classes. It revitalized me! It put me in contact with teachers who were excited about what they were doing. Even though they weren't all high school teachers – in fact a lot of them were elementary [teachers]. It just gave me a lot of ideas to bring back to my classes.*

Eleanor describes the relationship between interactions and teacher change:

> *Recharging and – really interacting with a group of other strong teachers and getting that recharge - the chance to recharge. Instead of giving, giving, giving – getting the opportunity to learn* (***acquisition***) *something new and really develop it and work it into something I could use in my classroom* (***synthesis***) *and be excited about.*

In addition to reporting changes in her enthusiasm, Eleanor suggests that a teacher's enthusiasm influences student achievement:

> *I am a strong believer in the idea that the kids need an enthusiastic teacher who is excited about their subject matter more than they need the world's foremost expert. The world's foremost expert may not be able to break it down for them. Right now I have a student teacher who has a Ph.D. in chemistry, but he disconnects with the students.*

Incidents of Action

The category *action* describes what is done during an interaction between teachers. *Action* comprises three properties: dissemination, acquisition, and synthesis. Figure **4-1** reveals the distribution of properties from the 78 incidents of action.

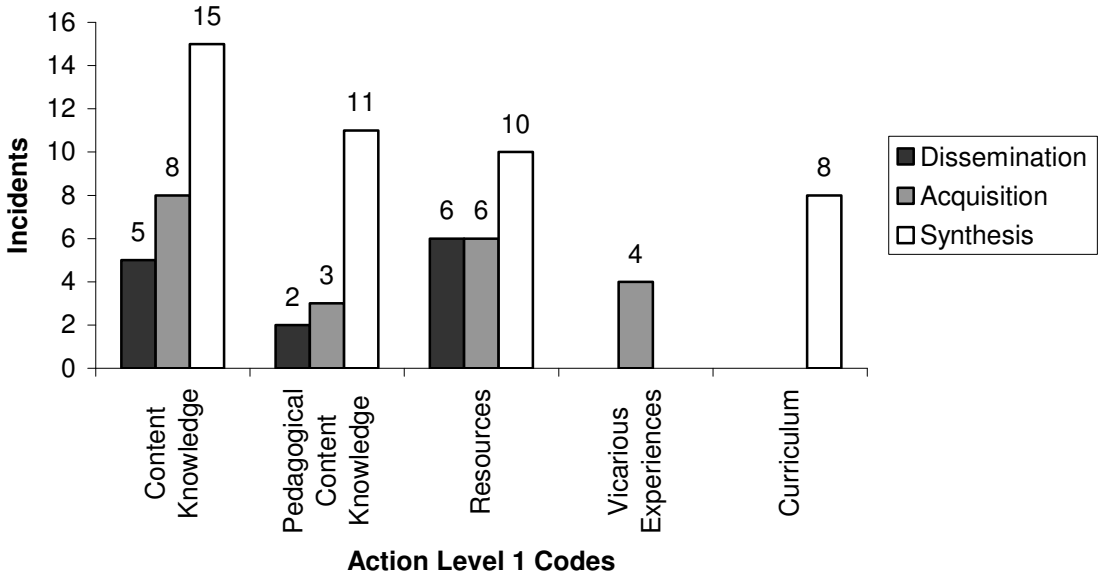

Figure 4-1: Incidents of Action

The category action comprises three properties: (a) dissemination, (b) acquisition, and (c) synthesis. The number of incidents reported for each property code reveals comparisons between properties and codes. The property synthesis occurs in 56.4% of the incidents of action. The codes are defined in Table 3-1.

Examples of action level 1 codes are listed in Appendix E.

Model of Actions

The property synthesis occurs in 56.4% of the incidents of action. This finding is important because synthesis is visualized as a convergence of dissemination and acquisition actions (Figure **4-2**). The model of actions implies that synthesis can only occur when participants integrate dissemination and acquisition. All incidents of mentoring reported in this study can be described using this model. Synthesis of information is exemplified by one TEA, "I never used graph predictions before working with him. Combining that with the data from the field allowed me to present the material much better." The TEA shared data collected during their field experience and received a new technique to apply in the classroom called graph predictions. This synthesis of information resulted in new pedagogical content knowledge.

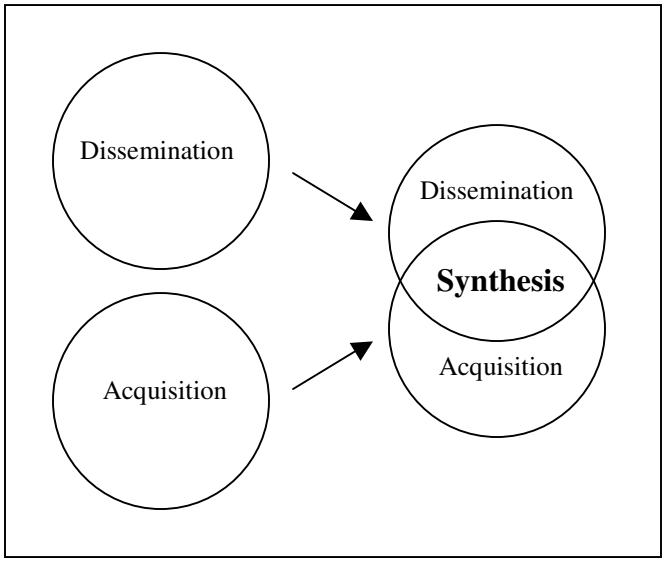

Figure 4-2: Model of Actions

The circles represent actions of dissemination and acquisition. Synthesis emerges as the circles converge.

Interaction

Each incident of teacher-to-teacher mentoring has an interaction that describes how information during a professional development engagement is delivered. The properties of interaction are authoritative and dialogic. Authoritative interactions involve a linear delivery of information. For example, a biology researcher presenting an overview of their research to a group of teachers is an authoritative interaction. The biology researcher has primary ownership of the information. Dialogic interactions involve a cyclical delivery of information. Each participant of a dialogic interaction brings information to the group and the information becomes collective property.

This next vignette includes both incidents of action and interaction marked with codes. The reason action and interaction are marked is to reveal that teacher-to-teacher mentoring is better understood using both categories than either one in isolation. Incidents of teacher mentoring described using the categories action and interaction are labeled engagements.

Vignette 2 – Victoria Bennett

Victoria is a high school science teacher at a charter school who became involved in collaboration with Rosalind after a colleague told her about Rosalind's marine science fieldwork in Antarctica. She reflected, "I was teaching marine science at the time and I thought it was very appropriate and I wanted to address – teach my children, my students the latest technology and information."

The interactions between Victoria and Rosalind took place after work beyond the contracted school day. The motivation for participation in these interactions is multifold, "One, because it builds me into a better teacher. We trade ideas (***dialogic***). We share ideas (***dialogic***). We have different interests so we bring… She comes from a chemical background and I come from an environmental background so we bring those things together. We think differently. We work well together bouncing ideas off each other." (***dialogic***). This description suggests curriculum development with an equal emphasis on disseminating and acquiring information (***dialogic/synthesis***).

Another engagement that evolved from this collaboration was the development and facilitation of an inquiry workshop for teachers. Descriptions of this workshop demonstrate two dimensions of interactions: (1) interactions between Victoria and Rosalind in preparation and implementation of the workshop, and (2) interactions between Victoria and workshop participants:

> *We worked together to develop an inquiry workshop for other teachers* (***dialogic/synthesis***) to *come to and that was probably one of the heights of our working together. We put together a workshop for about 20-40 teachers that showed up. We set up speakers and an agenda and teachers were to develop inquiry based lessons they could take back to their classrooms* (***dialogic/synthesis***). *We shared that with all the other teachers that were there* (***authoritative/dissemination***). *We put together a workbook for them* (***synthesis***). *We had researchers from Scripts that also came and spoke* (***authoritative/dissemination***). *That was one of the highlights of our adventure working together. She would also keep me up to date of teachers that were going to the Arctic or Antarctic and we would follow the teachers on their web casts and get photographs.*

Victoria's ownership in the success of the workshop is evident through her specific involvement:

> *I got in touch with one of the researchers and set up his information. Took his bio and finessed it and condensed it then prepared him when he came to speak at the program. We gathered lab reports from each of the teachers and put together a booklet* (***authoritative/acquisition***) *- Inquiry labs and activities booklet that the teachers had sent into us. We asked them to bring a cookbook lab that they could turn into an inquiry lab* (***synthesis***). *So I helped in compiling that. Making reservations. I set up behind the scenes at the aquarium here – down the street. Then, during the workshop itself we helped facilitate it.*

The workshop also provided Victoria with access to, "More real world experience. Science experience. Direct…through this experience we have met other scientists. We have met scientists that are willing to talk with our classes or take the student to the programs they offer."

Victoria describes several changes as a result of the interactions occurring during these engagements, "…my enthusiasm has increased. I would say in viewing me from that perspective…realizing that when you are a teacher you're on an island. It keeps my ideas fresher and including myself - definitely a benefit. Then I share what I learned with other teachers (***authoritative/dissemination***) in my school mainly, not so much outside the district. Only when I go to workshops and share things we've done. That's just part of the collaborative nature of teachers." The reported change suggests she is more likely engage in future professional development.

Victoria supports this claim of engagement in additional collaborations with a description of a recent effort, "…we wrote an energy grant and received a $10000 grant earlier this year. We worked on collaborating energy projects related to alternative energies for our AP Environmental Science courses. We gone of field trips together and we do some planning on that… we do some budget work together. We write labs…make

them more student-friendly (***dialogic/synthesis***). We basically been working a couple times a month for the last six months."

Incidents of Interaction

The category interaction describes the dialogue between participants of an engagement. The properties of interaction are authoritative and dialogic. Interactions were coded as authoritative when a single viewpoint is shared, access to participants is limited, the focus is dissemination, and transfer and ownership are low. Dialogic interactions possess value for multiple viewpoints, access to participants is easy or frequent, the focus is synthesis, and transfer and ownership are both high. Figure **4-3** reveals 65 incidents of interaction. Examples of interaction level 1 codes are listed in Appendix F.

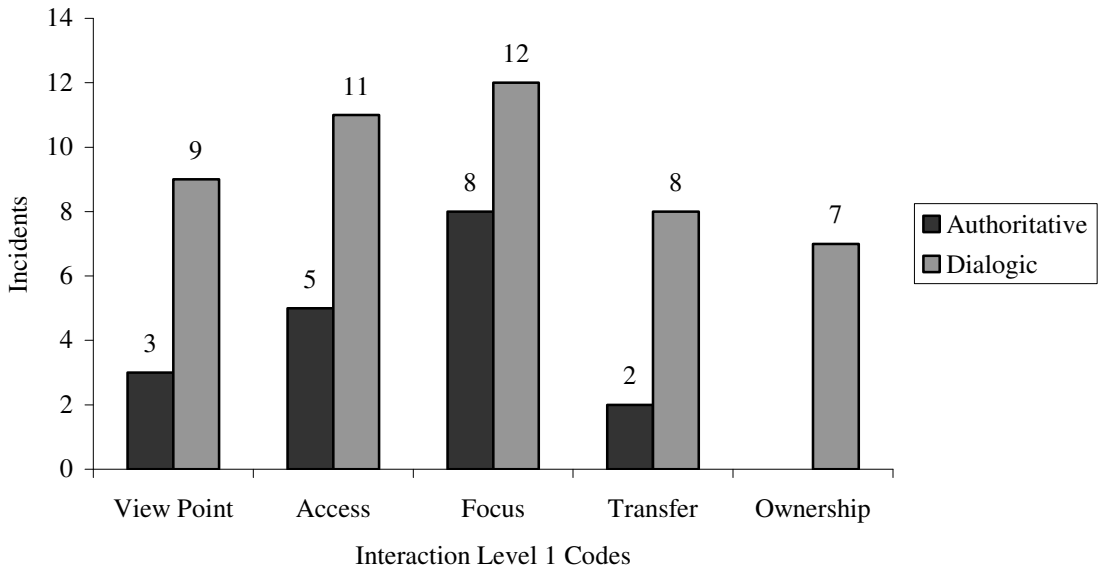

Figure 4-3: Incidents of Interaction

The category interaction comprises two properties, authoritative and dialogic. The number of incidents reported for each property code reveals comparisons between properties and codes. The property dialogic occurs in 72.3% of the incidents of interaction.

Teacher Engagement

Teacher engagements are events that occur at a specific point in time that facilitate interactions between teachers. All teacher engagements vary on continua depicting the relationships between the properties of action and interaction (Figure **4-4**). Dialogic and authoritative are established descriptions of interactions between teachers and students (Viiri & Saari, 2006). Authoritative interactions occur when the viewpoint is on one meaning (e.g., scientific understanding of natural phenomena) whereas dialogic interactions occur when there is recognition of multiple meanings (e.g., methodologies in classroom instruction) (Scott, Mortimer, & Aguiar, 2006). The same descriptions match participant descriptions of interactions between teachers.

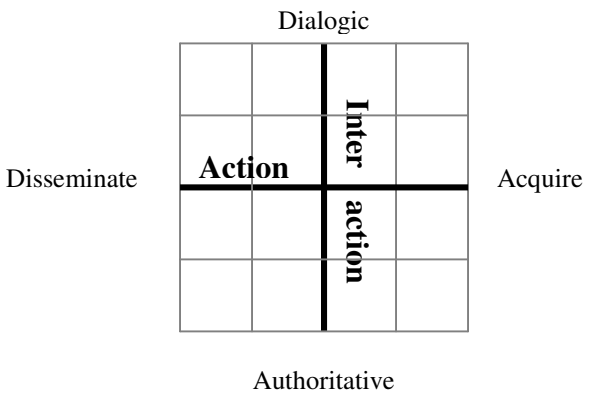

Figure 4-4: Engagement Mini-Framework

An incident of mentoring is described as an engagement comprising action and interaction. Engagements vary on continua that depict the relationship between the properties of action and interaction.

Model of Engagement

Engagements fall within three classification that describe the action and interaction: (1) dialogic-synthesis, (2) authoritative-dissemination, (3) authoritative-acquisition. Yet, the emergence of these engagement classifications does not directly reveal meaningful professional development. Professional development is labeled meaningful when teachers describe change. The conditions reported in each type of engagement described as meaningful are the degree of ownership of the engagement and dialogic interactions that result in a synthesis of information (Figure 4-5). Each example of teacher-to-teacher mentoring may be considered an engagement comprising an action and interaction. The action may be dissemination, acquisition, or synthesis. The interaction is either authoritative of dialogic. As ownership in an engagement increases, the engagement is more likely to be classified as a dialogic interaction and synthesis action. When ownership in an engagement diminishes, the engagement is more likely to be classified as either authoritative-dissemination or authoritative-acquisition. In the context of

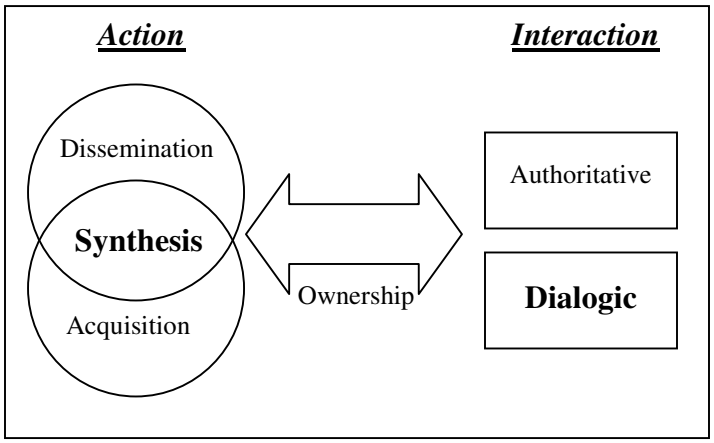

Figure 4-5: Model of Engagement

Any incident of mentoring can be described by the properties of action and interaction. Dialogic-synthesis engagements occur when participants have ownership in the action and interaction.

professional development, the value or meaning of an engagement may be measured by descriptions of teacher change.

Engagement Results

Teacher descriptions of incidents of mentoring also include changes that resulted from participation in the engagement. To contrast the experiences of the protégés teachers, the next vignette reveals the perspective of the mentor teacher (i.e., the TEA). The category *engagement results* has one property – teacher change. The teacher change section discusses the level 1 codes of this property in more detail and provides examples from the interviews that provide more depth to the *engagement results* category.

Vignette 3 – Rosalind Harding

Rosalind is a high school science teacher who participated in a research experience to the Arctic aboard a Swedish icebreaker as a component of the Teachers Experiencing Antarctica and the Arctic (TEA) program. One component of the TEA program required her to mentor three other teachers. Rosalind defines mentoring as, "…collaboration between the [protégés] and myself to bring science, better science, and real world experiences into the classroom. Work on lesson plans and discuss lesson plans after we've tried them to see what worked and what didn't."

Although Rosalind's motivation for entering into collaborations with teachers was extrinsic in the beginning, she describes several incidents that suggest intrinsic motivation:

> *I found that when we got together things just flowed. We were creative* (***synthesis***) *and we checked back with each other. We did a workshop together and overall for me it was a good experience. We would just sit at a table and go over lesson plans, we'd come up with labs* (***synthesis***)*, or we'd look on-line for labs we could all try. So we would bring, ok – in two weeks bring the lab that you do for the freezing point of water and salt mixture. Collaborate on these to see whose works out the best and we can give it a try when we get to that point in our curriculum* (***dialogic-synthesis***)*. I think they like the collaboration too. We got to do some great things together. We all got to go to the California Science Teachers Convention together. We put on the workshop together and it all worked out very well.*

Rosalind had interactions with her protégés and other teachers during the workshop they developed. She describes how these engagements transformed her professionally:

> *First, building better, stronger relationships with colleagues – new colleagues and old colleagues. Second, new labs that I got both from my [protégés] and the workshop that we put on because we had everyone submit a lab from the workshop – an inquiry-based lab. Better labs I would say because a lot of what we did was taking old labs, ones I've been using for fifteen years, and seeing what these new teachers were doing. I'd say my labs and curriculum improved as a result of the collaboration* (***teacher change***).

Incidents of Result

The category result describes the impact of an engagement. Teacher change is the sole property of the category result. Figure 4-6 reveals 63 incidents of the property teacher change. Examples of engagement results level 1 codes are listed in Appendix G.

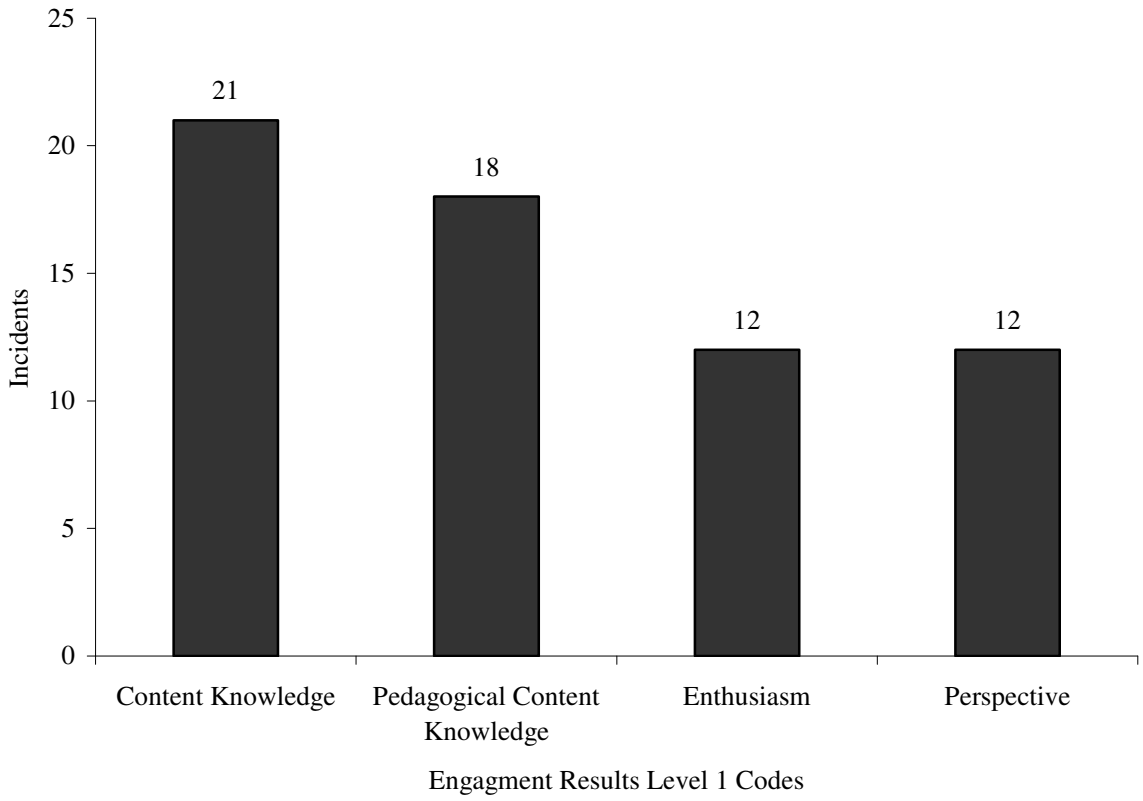

Figure 4-6: Incidents of Result

The category result has the property teacher change. The number of incidents reported for the property teacher change reveals the distribution of result codes.

Teacher Change

An engagement is an event that may promote teacher change. References to teacher change in this study are positive. Teacher changes are increases in knowledge, enthusiasm, and perspective. These changes to the teacher imply meaningful and productive professional development. Teachers' descriptions of the property teacher

change comprise four level 1 codes: content knowledge, pedagogical content knowledge, enthusiasm, and perspective. These level 1 codes do not emerge from a single incident of engagement. Rather, the level 1 codes reflect a menagerie of engagements by participants

Content Knowledge

Teacher change in content knowledge reflects an acquisition of subject matter understanding. Subject matter is not restricted to the teacher's content area of specialization. Indeed, some teachers specify their content knowledge increased in areas outside their expertise. As an exemplar, one Biology teacher described her exposure to Physics as meaningful because it expanded the breadth of her scientific understanding, "Now I am more knowledgeable in the area so I am comfortable talking with them about their field versus mine."

Content knowledge also refers to the nature of science and the different methods of scientific inquiry. One catalyst for the acquisition of this type of content knowledge is through vicarious experiences teachers have access to via their mentors. Teachers are drawn into professional development efforts by an opportunity to learn about exotic locations, fieldwork logistics, and survival in extreme environmental conditions. These vicarious experiences provide teachers with exposure to contemporary science.

Pedagogical Content Knowledge

Pedagogical content knowledge (PCK) is a special type of teacher knowledge acquired by experienced teachers (Shulman, 1986). PCK includes understanding what concepts are most appropriate for students at a specific age, what constructs students bring into the classroom, and the techniques that are more effective with aligning student understanding with that of science.

One example of PCK described by teachers is the utilization of science inquiry methods. Teachers describe changes in their pedagogy as going beyond the textbook and presenting real world applications for math and science. Representative of the participants in this study, Mary Anning, describes change in PCK by using data derived from a TEA's research experience in their classroom:

> One thing that sticks out is working with Weddell seals and the other seals – I can't think of what it was [species of seal]…and their speed, and their time they are under the water, and the time they come out of the water. Which one can stay longer? How much time did they need? Distance. Speed that they used. They would research how fast they could swim. How long they could stay under water.

Enthusiasm

In this study, many teachers describe feeling isolated in their classroom. Interacting with other during engagements erodes this isolation. Teachers describe this erosion using words such as enthusiasm, recharging, excitement, etc. Teachers argue professional renewal is a fundamental characteristic of an effective teacher because the enthusiasm transfers to students and many influence student achievement. Arthur

Holmes, a mathematics teacher from Tennessee, describes changes in his enthusiasm from interactions:

> *I love being on the cutting edge of what is going on. Being able to actually connect with the scientists where that is the hard thing is being in the academic world and high school world you have to take books and things which you don't have any real connections with scientists. So, this way – through her – I could make a connection and also when you get with other people that are interested and excited it kind of rejuvenates you as far as teaching. Because isolation can kind of beat you down a little bit in education so it is nice to get around other people that are enthusiastic. And, so when you can find a project that you can get enthusiastic about working on then it makes it all worthwhile – something that you both enjoy learning but also applying to your classroom. I think when you got someone who is around people that have both love for life and for teaching it makes you recharged or increases your level of enthusiasm. After a meeting or get together it would help you get more energetic when you back to your classroom and were excited about what you were doing.*

Perspective

Perspective describes how teachers view the world and people around them. Teachers describe changes to perspectives through three lenses. First, there are changes to their perspective of themselves as individuals. One teacher specifically describes changes to her confidence as a leader. Her collaborations with her mentor resulted in an altered self-perception that facilitated her entry into more leadership position. For example, she began leading teacher workshops.

A different lens of perspective is how teachers view students. Teachers often describe surprise and delight with the achievement of their students. A teacher commented, "…we had the graphs themselves and how they were designed and know that eighth graders would be willing to take the time and the graphs were just

phenomenal – what my kids put together. They really blew me away [with] what they could do."

The final lens for perspective regards science itself. Teachers comment how the exposure they had during the engagements changed their perspective on the types of science. For example, one teacher participated in a workshop on foraminifera. Foraminifera are microscopic single-celled organisms with carbonate skeletons (e.g. shells) often found in marine sediments. Foraminifera were the focus of the workshop because the protégés TEA studied foraminifera during their field experience. The protégé commented, " I had no idea such fossilized creatures existed in my own county – yet alone the existence of the study of foraminifera."

Teacher Change Summary

The types of changes teachers describe occur predominately through dialogic-synthesis engagements (Figure 4-7). The changes reported are indicators of meaningful professional development. It is important to note that interviewees not only report the meaningful interactions, but many also state these interactions took place in the distant past, sometimes several years ago.

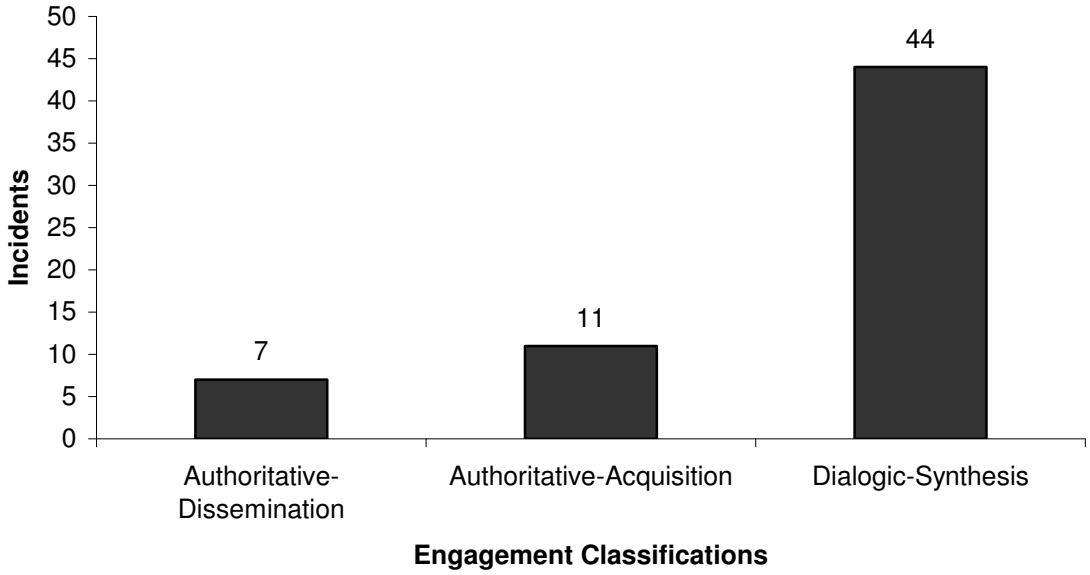

Figure 4-7: Incidents Related to Teacher Change

There are three classification types that describe engagements: (a) authoritative-dissemination, (b) authoritative-acquisition, and dialogic-synthesis. The distribution of engagement types related to teacher change reveal 71% of the incidents of teacher change occurred during dialogic-synthesis engagements.

The data suggest that dialogic-synthesis engagements are not only meaningful, but also long lasting. For instance, 50 percent of the protégés interviewed did not remember specifics about a TEAs research experience – an authoritative-acquisition type of engagement. Two protégés used to construct the vignettes, support this claim:

> *I cannot remember what she did in the Arctic. I know she was taking ice samples and I know she worked with other people taking scrapings and pulling bacteria off of some of the fog that was on the windshield.*
>
> *I don't know that much about the actual trip itself. I know that she was working for a scientist. That she was doing some sampling of water. I don't know all of the details of exactly what she did on the trip itself.*

Professional Development Model

Engagements are described on a continuum between the dissemination and acquisition of information through interactions with people. When there is a balance between information dissemination and acquisition the interaction results in a synthesis of information. An observation of synthesis can only occur during dialogic interactions. For example, a teacher may synthesize information during an authoritative-acquisition engagement. However, this synthesis of information is hidden from observation unless reported.

The data reveals that engagements that result in reported teacher change are categorized as dialogic-synthesis. Dialogic interactions increase ownership in an engagement making it more meaningful. In other words, the ownership and meaning of an engagement are directly related to reported teacher changes. This relationship is

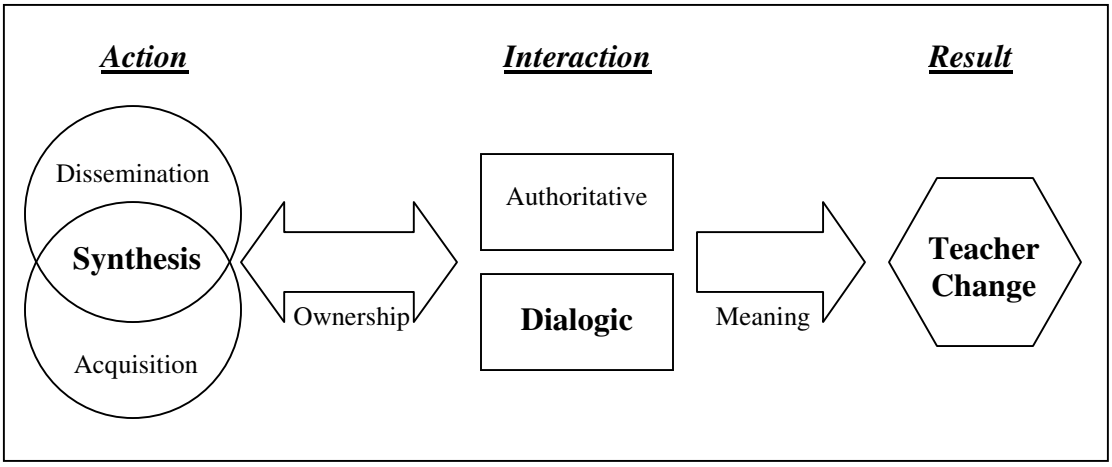

Figure 4-8: Professional Development Model of Teacher Mentoring

This professional development model depicts how an engagement comprising synthesis actions and dialogic interactions facilitates teacher change. Teacher change is mediated by the degree of ownership and meaning of an engagement.

depicted in a professional development model that shows how a dialogic-synthesis engagement may result in teacher change (Figure 4-8).

The action portion of the diagram reveals that the convergence of dissemination and acquisition results in synthesis. The interaction component of an engagement is either authoritative or dialogic. The synthesis-dialogic engagement classification shown in this model is influenced by the amount of ownership participants have in the engagement. Ownership is a two-way arrow because synthesis actions facilitate dialogic interactions and vice versa. For example, it is unlikely that an authoritative interaction will entail a synthesis action.

Dialogic-synthesis engagements result in teacher change. The relationship between an engagement and teacher change is shown with a one-way arrow that represents the meaning of the engagement to teachers. The findings of this study only support a one-way arrow between an engagement and teacher change. However, future research may reveal that teacher change results in further engagements.

The findings of this research do reveal that dialogic-synthesis engagements result in teacher change as exemplified with the bold font in the model. This model represents the engagements described by all participants in this study. The catalysts for entry into this professional development model were an authentic research experience by a mentor teacher and interactions related to problems of practice.

Summary

The mentoring experiences described by the teachers in this study can be understood using the professional development model of teacher mentoring shown in Figure 4-8. How meaningful a mentoring experience is to a teacher is influenced by the degree of ownership in an engagement. The more ownership a teacher has in an engagement the more likely that action will result in the synthesis of information. The three classifications of an engagement are: (1) authoritative-dissemination, (2) authoritative-acquisition, and (3) dialogic-synthesis.

When actions during an engagement are strictly either dissemination or acquisition of information, the interactions are authoritative. At the heart of the professional development model of teacher mentoring is the interaction. Interactions that are dialogic require the synthesis of information dissemination and acquisition. Dialogic interactions are directly related to ownership in an engagement because any dialogic interaction involves active participation from all participants. Thus, the findings of this study indicate that dialogic-synthesis engagements result in teacher change.

In the final chapter I discuss how I integrate these findings into educational research on teacher learning and professional development. Then, I will discuss the implications this work has for further research in these areas. The chapter concludes with several questions for future research.

Chapter 5

Conclusion and Implications

Introduction

In this chapter the findings of this study are discussed with a focus on meaningful interactions among teachers as professional development. The background literature in Chapter 2 revealed teachers often work in isolation (Lortie, 1975) and traditional professional development models are not meaningful to teachers (Hawley and Valli, 1999). Meaningful professional development efforts that do exist are often supported by university/school partnership and are thus limited in their impact (Marx et al, 1998). Further, little attention has been devoted to professional development collaborations between in-service teachers – i.e., teacher-to-teacher mentoring (Darling-Hammond, 1998). To better understand meaningful teacher interactions, this study was guided by the following questions:

1. *How do meaningful interactions among teacher occur?*
2. *How do teachers describe professional collaborations associated with authentic science research experiences?*
3. *What elements of interactions among teachers are meaningful?*
4. *Why are these elements of interactions meaningful to teachers?*

This chapter begins with a concise summary of the findings. The findings are placed in context of research on professional development and teacher change. Next, the implications of these findings are discussed with a focus on professional development

resulting in teacher change through a constructivist perspective. The chapter concludes with an outline of future research.

Summary of Findings

An individual teachers' participation in an authentic science research experience is often a limited form of professional development: a linear experience that happens once to a single teacher (Dresner and Worley, 2006). In contrast, the interactions between mentors and protégés are cyclical and involve the professional development of many teachers. Providing professional development that facilitates interactions among teachers is difficult because teachers work in isolation (Lortie, 1975) and typical engagements are fragmented and not meaningful (Loucks-Hoursley and Matsumoto, 1999). Teachers involved in the mentoring component of the Teachers Experiencing Antarctica and the Arctic (TEA) program reveal how meaningful interactions among teachers occur.

How Do Meaningful Interactions Among Teachers Occur?

Meaningful interactions among teachers occur when there is teacher change, such as gaining new pedagogical knowledge. The construction of knowledge can be viewed as personal or social (Tobin and Tippins, 1993). Given that dissatisfaction with a priori understanding is necessary for the assimilation of new knowledge, Van Glaserfeld (1998) highlights the social aspect of learning with, "it is necessary to emphasize that the most

frequent source of perturbations for the developing cognitive subject is the interactions with others." (p. 128). This notion provides insight into the importance of professional development efforts that involve collaborations and peer networks because they better align with constructivist's theory of learning.

A constructivist approach to professional development stands in stark contrast to behaviorism and maturationism. Behaviorism is the scientific study of behavior relying upon behavioral responses to physical stimuli (Galotti, 1998). Behaviorism's popularity stemmed from the ease in studying behavior in contrast to unobservable thoughts inside a person's head. Maturationism is described by Fosnot (1996) as, "…a theory that describes conceptual knowledge as dependent on the developmental stage of the learner, which in turn is the result of innate biological programming." (p. 9). The focus of constructivism is the active reorganization of knowledge and, with regard to professional development; knowledge is not an independent entity (Tobin and Tippins, 1993). Thus, constructivism stands apart from other theories of learning by the emphasis placed on the individual's prior knowledge and their interaction with the environment.

For professional development efforts to be effective, the social and cultural dynamics of a teacher's environment are important (R. T. Putnam & Borko, 1996). For instance, Fosnot (1996) offers, "We cannot understand an individual's cognitive structure without observing it interacting in a context, within a culture." (p. 24). Thus, the extraction of teacher's prior knowledge in the context of their environment is necessary for learning to occur. Contradictions to a priori knowledge are particularly important, especially if the construction of new knowledge is socially negotiated.

Opponents of constructivism argue that subscribing to a constructivist philosophy requires accepting there is no reality or universal truth (Tobin and Tippins, 1993). However, this is an ontological argument. Rather than devoting attention to the nature of being, constructivists argue that reality can only be understood in a personal and subjective way (Tobin & Tippins, 1993). The subjectivity of constructivism dictates that there is no authority monopolizing knowledge. Any authority that may appear dominant is a manifestation of society. In the context of teaching, Tobin and Tippins state, "… it is the teacher's duty as a professional to structure learning environments to facilitate the process of learning what society regards as having greatest viability at that particular time." (p. 5).

A constructivist perspective places more emphasis on diverse viewpoints than other perspectives. Tobin and Tippins (1993) reinforce this stance with, "[t]he recognition that knowledge has both individual and social components that cannot be meaningfully separated enables us to construct science learning environments where multiple ways of knowing (i.e., women's ways of knowing, indigenous people's way of knowing) are sought and valued." (p. 6). The recognition that there are multiple ways of knowing affords acceptance of diverse pedagogies and problems of practice. For example, each teacher in this study had individual knowledge of pedagogy and brought their own problems of practice to the mentoring engagements. The social components of the interactions allowed exposure to experiences. Therefore, constructivism not only mandates reducing the isolation of teachers in their professional development efforts, but also recognizing the importance of diversity. The influence of diverse ideas on learning

is evident through the response a teacher provided when asked how they increased their science knowledge:

> *It is through the different interactions with teachers at the programs and seeing some of the things they do and talk about, especially in different class areas. It helped broaden my range of knowledge, what I cover and how things are covered in the different classes.*

Dialogic interactions by definition require multiple participants. In addition, engagements that comprise actions of synthesis result from interactions between people. The meaningful interactions described in this study that resulted in teacher change align with standards for professional development for teachers of science and were connected to teacher's work in their classrooms. The National Research Council (1996) states:

> *Although learning science might take place in a science laboratory, learning to teach science needs to take place through interactions with practitioners in places where students are learning science, such as in classrooms and schools.* (p.58)

This need supports an argument for better understanding meaningful interactions among teachers. The descriptions shared by the teachers in this study reveal meaningful interactions occur when there is ownership in an engagement that provides them access to collaborate with others. Ownership in an engagement supports dialogic interactions comprising: (a) diverse view points, (b) easy and frequent access to participants, (c) inquiry focus, and (d) high transfer to the classroom.

How Do Teachers Describe Professional Collaborations Associated with Authentic Science Research Experiences?

The vignettes from Chapter 4 provided rich descriptions of professional collaborations associated with authentic science research experiences. These vignettes

highlight three engagement classifications of mentoring between teaching: (a) authoritative-dissemination, (b) authoritative-acquisition, and (c) dialogic-synthesis. Although authentic science research experiences were the catalyst for the collaborations, protégés reported not remembering much about the expeditions. This observation does not imply that authentic science research experiences are not meaningful; rather it reveals that the engagements classified as dialogic-synthesis were more meaningful for the protégés. Dialogic interactions are social by nature. However, synthesis actions may be either social or personal endeavors.

Clement and Vandenberghe (2000) argue that professional development is best facilitated in schools where collegiality and autonomy are both encouraged. Instead of a polar view of these terms, the two must be cyclical in nature - a view influenced by the school organization. Descriptions of professional development by protégés align with a cyclical view of collegiality and autonomy. The dialogic interactions the protégés have with a TEA increases collegiality and each teacher has autonomy to enact changes in their classroom.

Teacher interactions that occur through participation in a community increase teacher learning (Loucks-Horsley and Matsumoto, 1999). The collaborations between teachers in this study reveal an increase in teacher content knowledge. Teacher content knowledge influences instructional practice (Putnam and Borko, 1996). Teachers also report changes to their pedagogical content knowledge, often with descriptions related to incorporated science inquiry into their classroom. Shulman (1986) describes pedagogical content knowledge as:

> "…the ways of representing and formulating the subject that make it comprehensible to other. Since there are no single most powerful forms of representations, the teachers must have at hand a veritable armamentarium of alternative forms of representation, some of which derive from research whereas other originate in the wisdom of practice." (p. 9).

Reducing isolation and increasing participation in a community of practice also changed the enthusiasm and perspective of teachers. Several teachers in this study report that effective teaching is related to the enthusiasm they bring into the classroom. The professional collaborations in this study also provide descriptions of changed perspectives. These altered perspectives result from exposure to types of science that are new to participants and renewed understanding of students' capabilities. Teacher descriptions of professional collaborations associated with authentic science research experiences can be summarized as meaningful.

What Elements of Interactions Among Teachers Are Meaningful?

Interactions among teachers are described in this study as either authoritative or dialogic. Dialogic interactions among teachers are reported as meaningful because they facilitated teacher change. The synthesis of ideas and information resulting from these interactions instilled ownership, which is the critical mediating factor between an engagement and teacher change.

Collaboration between peers and researchers may also facilitate teacher change. Blumenfeld et al (1994) emphasized a change in viewing the role of a teacher as a transmitter of knowledge to facilitating opportunities supporting social constructivist theory on learning. Rather than the standard workshop involving the dissemination of

knowledge, their efforts were dialectic. The collaboration between teachers and researchers described by Blumenfeld et al. (1994) are viewed as authoritative because the study focused on teachers enacting a specific instructional program utilizing a constructivist theory of learning.

Another perspective on meaningful interaction is between teachers and students. Scott et al (2006) argue that tension between authoritative and dialogic interactions is necessary for it to be meaningful to students. Dialogic is defined as interactions that recognize various points of views whereas authoritative recognizes only one point of view. Teacher professional development may have parallel elements - specifically if the goal is to increase science content knowledge. However, if the goal is to change pedogical content knowledge there is a problem - no single "correct" view exists (Shulman, 1986). Thus, any authoritative stance must be generated by dialogic interactions between teachers. Professional discussions between teachers have been found to improve their effectiveness as teachers (Dunn and Shriner, 1999).

Why Are These Elements of Interactions Meaningful to Teachers?

Dialogic interactions between teachers are meaningful because this type of interaction increases ownership in an engagement. Collaborating on the development and delivery of a workshop or other engagement resulted in teachers reporting changes to their knowledge, enthusiasm, and perspectives. Blumenfeld et al (1994) report, “Successful collaboration required that participants see themselves as a community with

a shared investment in the endeavor." One endeavor shared by many teachers was the enactment of science inquiry in their classrooms.

Enacting pedagogy of science inquiry is difficult for teachers because science inquiry is an elusive classroom strategy. Science inquiry may be nebulous because each area of science has its own traditions and methods of understanding natural phenomena. Access to other teachers provided teachers an opportunity to explore this pedagogy further. Darling-Hammond and Baratz-Snowden (2007) found, "…the process of learning to enact new skills is best supported by skilled coaching in peer-support groups that allow teachers to develop, strengthen, and refine teaching skills together." This process of learning correlates with the findings of this study.

The elements of interactions reported in the study are also meaningful to teachers because they reduce isolation by nurturing professional dialogue between teachers – especially between teachers of different content areas. For instance, teachers report the erosion of barriers between different content area teachers and increased ease in the use of other teachers as resources. This included increased dialogue with teachers not involved with the TEA program.

Conclusions

The results of this study indicate mentoring among teachers is a meaningful form of professional development that can result in teacher change. My use of the word mentoring, however, does not fall within its common definition. Rather, mentoring is used as a shared experience between people. Each person contributes or brings

something important to the interaction. Neither is this relationship adequately described by using the word interaction. Mentoring and interactions must be used together. In the context of this study, mentoring may be better described as parallel mentoring. Each teacher has something to contribute to the interaction.

Mentoring interactions described as dialogic encourage synthesis actions. The engagements described in this study revealed collaborative professional development efforts among teachers who had equal ownership in the success of the engagement. Such efforts were meaningful to teachers because it removed feelings of isolation from the practice of teachers and nourished a professional community of practice resulting in teacher change.

Implications

This study has implications for understanding teacher centered professional development, policy, and education research.

Teacher Centered Professional Development

The professional development of teachers on the district and national level is often fragmented, and is commonly disseminated using a top-down approach. When teachers have ownership in the professional development, it becomes more meaningful because there is much greater opportunity for teacher change. This study provides a

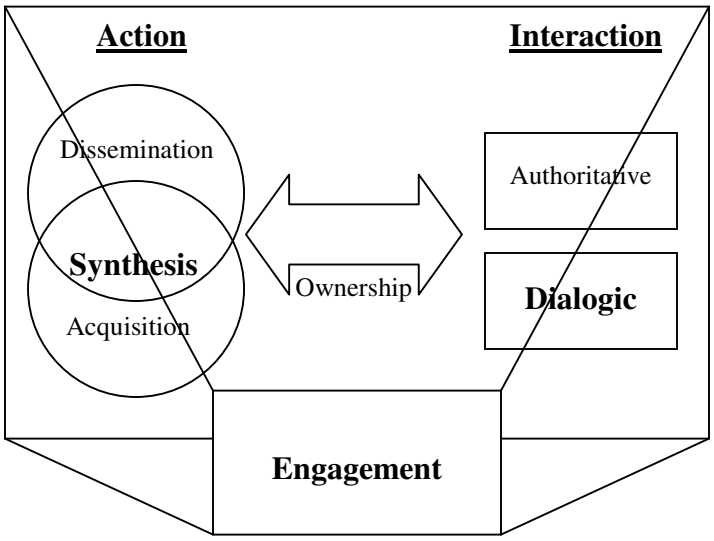

Figure 5-1: Dialogic-Synthesis Engagement Model

An engagement designed as dialogic-synthesis may facilitate teacher change. Use of this model encourages program designers to incorporate dialogic interactions and synthesis actions into professional development offerings.

theoretical professional development model of teacher mentoring relating teacher change to ownership and meaning. The common factor equating ownership and meaning is the problem of practice. Teachers bring problems of practice to the engagements. The engagement is meaningful because resolving the problem of practice is the motivation for participation. Both mediators of teacher change increase through synthesis actions and dialogic interactions. A teacher's approach to a professional development engagement

may be influenced by the recognition of the elements of this professional development model (Figure **5-1**). For example, a department engaged in rewriting curricula may enter the process as opportunities to dialogically interact with peers while synthesizing innovative curricula. The teachers rewriting a curriculum may work around problems of practice such as the incorporation of science inquiry methodologies (Wee et al, 2007). This approach is in contrast to typical curriculum revisions I have experienced that occur in isolation and merely align current curriculum with a predetermined template.

A major implication of this study is that the professional development of teachers should not occur in isolation. Any professional development program would benefit from pre-arranged interactions among teachers. For example, teachers should attend professional development offerings as teams so interactions can occur in context and continue when the teachers return to their school.

Policy

Many teacher enrichment programs provide innovative and unique opportunities for teachers. The programs often involve the dissemination of information through interactions that are authoritative. For example, a typical summer workshop for teacher may consist of attending daily lectures and also the dissemination of resources. The facilitators of such workshops can make the engagement more meaningful to teachers if they design dialogic interactions that involve the synthesis of information into the workshop curriculum. For example, a workshop planned for middle school teachers on high-energy physics presented in a didactic manner may only change teachers' content

knowledge. Even such a change in the teacher's content knowledge may be limited because the content may not easily transfer to the classroom. A more meaningful approach may require altering a lecture from transmitting what science understands about high-energy cosmic radiation to how science constructed the understanding of the phenomena. A concrete example may help explain this process.

An electroscope is a simple device made from a glass bottle. Inside the bottle is a conductive wire suspended by a rubber stop with metal foil draped like a pair of pants on a hanger. When a charge is inducted into the wire the drapes of foil move apart due to the electromagnetic force. Theoretically, the drapes should remain apart until the charge is removed. However, over time the drapes eventually reunite indicating something stripped the foil of its charge. The identification of this mysterious thief resulted in the birth of astroparticle physics. Teachers introduced to high-energy physics may create an electroscope during a workshop and interact with each other synthesizing classroom applications. This type of interaction can be facilitated through deliberate inclusion of dialogic interactions and synthesis of information in the workshop curriculum.

Another implication for developers of teacher enrichment programs that require mentoring is that less emphasis should be placed on the *time* teachers mentor (i.e., number of hours) and greater emphasis placed on developing and implementing meaningful mentoring activities. The professional development model of teacher mentoring informs developers how meaningful mentoring occurs. The mentoring component of a program can require teachers to interact developing a workshop or in-service program with a theme relevant to the program. For example, a science teacher returning from an authentic science research experience can interact with math and

science teachers to develop an in-service program focusing on the development of strategies for teaching students to use various graphical representations of data to better strengthen arguments about a particular phenomenon.

Education Research

Research on the impact of traditional professional development on teacher learning is rarely based on empirical evidence (Wilson and Berne, 1999). This has resulted in redefining meaningful professional development models to better align with a constructivist perspective of learning (Putnam and Borko, 1996). Professional development models that value interactions between participants adhere to one tenet of constructivism that learning is a social phenomena. Putnam and Borko (1996) summarize the social nature of cognition; "…knowledge and thinking are the products of interactions among groups of people over time." (p. 1253).

The professional development model of teacher mentoring proposed in this study aligns with the social constructivist's view of teacher learning. The model also encourages the development of communities of practice. Participation in a community of practice facilitates teacher learning (Loucks-Horsley and Matsumoto, 1999). Research in education reveals three conceptions of teacher learning: (1) knowledge-*for*-practice, (2) knowledge-*in*-practice, and (3) knowledge-*of*-practice (Cochran-Smith and Lytle, 1999). Knowledge-*for*-practice refers to the formal knowledge base of teachers comprising content knowledge and pedagogical knowledge. Knowledge-*in*-practice is acquired in the context of the classroom and is often viewed as practical knowledge. Knowledge-*of*-

practice is generated by teachers through deliberate inquiry into their classroom practice. Cochran-Smith and Lytle (1999) reveal the contexts that knowledge-*of*-practice are generated, "Teacher networks, inquiry communities, and other school-based collectives in which teacher and other conjoin their efforts to construct knowledge…" (p. 273).

The teachers in this study may be viewed as inquiry communities. The commonality between each incident of teacher-to-teacher mentoring is inquiry into problems of practice (e.g. curriculum or science inquiry). Professional learning increases during the codevelopment of curriculum (Loucks-Horsely and Matsumoto, 1999). The knowledge generated by the teachers in this study cannot be attributed to a single teacher. Rather, the knowledge is generated collectively, situated in the context of the classroom.

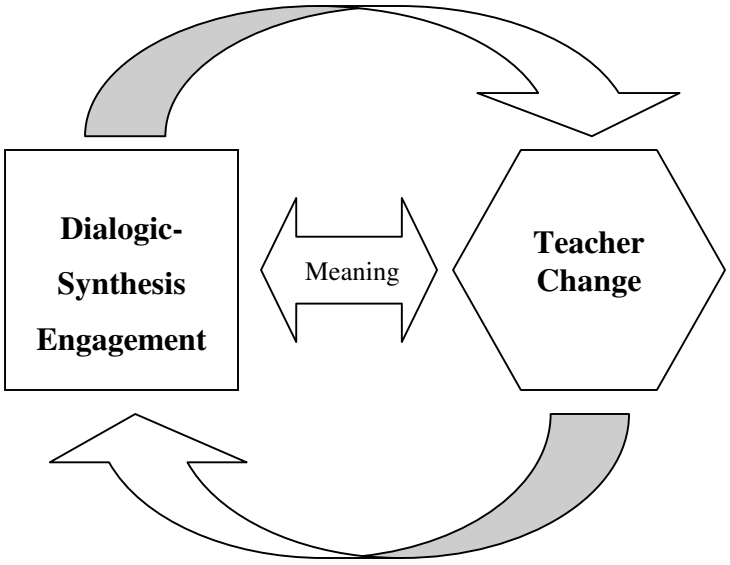

Figure 5-2: Cyclical View of Engagements and Teacher Change

Teacher change as a result of dialogic-synthesis engagements may lead to further involvement in this engagement classification. Meaning mediates the cyclical nature of this model.

Teacher learning is shown as a cyclical relationship between an engagement and teacher change (Figure **5-2**). This study reveals dialogic-synthesis engagements result in teacher change. Teacher report these

engagement classifications as meaningful. Teachers experiencing change may be more inclined to pursue further professional development offering that are classified as dialogic-synthesis. The catalyst for entry into this model may be inquiry into problems of practice.

Future Research

The results of this study indicate several areas of important future research.

1. The teacher change described in this study was a result of teacher engagements described as dialogic mentoring interactions and synthesis actions. Further exploration of this model is necessary to better understanding if teacher changes from these particular styles of engagement result in future engagements of the same style, i.e., determine whether the model is more cyclical than depicted.

2. The model of professional development of teacher mentoring discovered in this study emerged from participants in one National Science Foundation (NSF) Teacher Enrichment program. It would be interesting to see if the model can be generalized to other types of professional development. For instance, can the resources invested to provide a summer workshop for teachers have a better return by including a mentoring component informed by this model.

3. This study involved researching mentoring interactions betweens teachers involved in an authentic scientific research experience and teachers who did not participate in such a field experience. The catalyst for the interactions was the field experience. An interesting test for the model is replacing the catalyst.

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Appendix A

TEA Participants as Partners and Mentors

- Several opportunities exist for TEAs to act as partners and mentors:
- Following the field experience, the TEA teacher may be asked to serve as a partner to **new TEA participants**. This will involve meeting the new TEA at the summer orientation workshop, presenting information about the field experience, and serving as a resource for the new TEA in the time before and during the research experience.

- Each TEA is required to **mentor a minimum of three peer teachers for a minimum of 137 hours each over a period of three years**. This is "face to face" time. These teachers are considered TEA Associates. Mentoring is a critical component of the TEA Program. It is an opportunity for development of content knowledge and teaching/facilitation practices for the TEA and for the mentoree. Mentoring allows the TEA to share the research experience, and ideas for bringing research into the classroom with others. Just as we hope students become immersed in investigations, the mentoring experience should be an immersion in the research experience for the TEA and two or three peers. The mentoring will be documented by the TEA and each of the three "mentorees" and shared electronically with the TEA community and with NSF.

- The TEA can lead local **TEA Associates** networks. Associates are an integral component of the Polar Learning Community and will incorporate the TEA on-line journals, CU-SeeMe sessions, and Q/A potential in their classrooms during the TEA field season. The TEA will be available to answer questions, visit the classrooms to speak with the students about the research experience, host local workshops to develop plans for integrating the TEA experience into the curriculum, etc. Associates are invited to participate in all discussions on the TEA Web site, attend TEA meetings (limited funding available) and to submit activities and ideas. Associates are available to serve as pilot- classrooms for the activities developed by the TEAs.

The specific responsibilities and obligations of TEAs varied from year to year. This list reflects the mentoring obligations from the 2001-2002 cohort. This list and other obligations to the program can be retrieved from:

http://tea.armadaproject.org/teainfo/TEA_01_02_Responsibilities.html

Appendix B

TEA Survey Form

Teachers Experiencing the Antarctic and Arctic Mentoring Survey

Please supply your contact information:

Name: _____

Title: _____

Organization: _____

Address: _____

City, State, and Zip Code: _____

E-Mail: _____

Phone Number: _____

Age: _____ Gender: _____ Years of teaching experience: _____

Year you become a TEA: _____

Grade Level (circle all that apply): Elementary Middle High School Other

Teachers mentored:

1. Name: _____

Age: _____ Gender: _____ Years of teaching experience: _____

Geographic distance between your school and their school: _____

Number of completed mentoring hours: _____

Is this mentored teacher still active in your mentoring efforts? _____

If no, please provide a brief reason the person is no longer active:

_____

2. Name: _____

Age: _____ Gender: _____ Years of teaching experience: _____

Geographic distance between your school and their school: _____

Number of completed mentoring hours: _____

Is this mentored teacher still active in your mentoring efforts? _____

If no, please provide a brief reason the person is no longer active:

_____

3. Name: _____

Age: _____ Gender: _____ Years of teaching experience: _____

Geographic distance between your school and their school: _____

Number of completed mentoring hours: _____

Is this mentored teacher still active in your mentoring efforts? _____

If no, please provide a brief reason the person is no longer active:

_____

4. Name: _____

Age: _____ Gender: _____ Years of teaching experience: _____

Geographic distance between your school and their school: _____

Number of completed mentoring hours: _____

Is this mentored teacher still active in your mentoring efforts? _____

If no, please provide a brief reason the person is no longer active: _____

5. Name: _____

Age: _____ Gender: _____ Years of teaching experience: _____

Geographic distance between your school and their school: _____

Number of completed mentoring hours: _____

Is this mentored teacher still active in your mentoring efforts? _____

If no, please provide a brief reason the person is no longer active: _____

_____

On average, how often do you meet with the mentored teachers? (circle one)

Daily Weekly Monthly

On average, how many hours do you meet with the mentored teachers each session?

_____

Please indicate your level of agreement with the following statements: (circle one)

1. I am comfortable with the mentoring process.

Strongly agree Agree Neutral Disagree Strongly disagree

2. I have a clear understanding of the mentoring process.

Strongly agree Agree Neutral Disagree Strongly disagree

3. I received adequate training on mentoring.

Strongly agree Agree Neutral Disagree Strongly disagree

4. The mentoring experience has been valuable.

Strongly agree Agree Neutral Disagree Strongly disagree

5. I expect to fulfill my mentoring obligations.

Strongly agree Agree Neutral Disagree Strongly disagree

6. The number of required mentoring hours is appropriate.

Strongly agree Agree Neutral Disagree Strongly disagree

Please answer the following open-ended questions using the space provided:

1. The greatest challenge of mentoring is _____

_____

2. The TEA Program mentoring component can be improved by _____

_____

3. The greatest reward of mentoring other teachers is _____

_____

Appendix C

Survey Questions

Select the response that best answers the following questions.

1. How would you rate your interaction with your TEA teacher?

___ Very Meaningful
___ Meaningful
___ Little Meaning
___ Not Meaningful

2. How willing would you be to participate in the TEA program again?

___ Very Willing
___ Willing
___ Slightly Willing
___ Not Willing

Select the response(s) that best answer the following questions.

3. What did you anticipate to gain from the interaction?

___ Science Knowledge
___ Polar Knowledge
___ Pedagogical Knowledge
___ Curriculum Materials
___ Access to Scientists
___ Access to Teachers
___ Opportunity to Travel
___ Compensation
___ Continuing Education Credits
___ Other
___ Nothing

4. What aspects of the interaction remain most valuable to you today?

___ Science Knowledge
___ Polar Knowledge
___ Pedagogical Knowledge

___ Curriculum Materials
___ Access to Scientists
___ Access to Teachers
___ Opportunity to Travel
___ Compensation
___ Continuing Education Credits
___ Other
___ Nothing

5. Would you agree to a follow-up interview?

___ Yes ___ No

If yes, please provide contact information below:

Appendix D

Reflective Memo

After transcribing other interviews, my initial ideas continue to evolve. At first, I thought that specific incidents could be categorized according to capital: 1. Social, 2. Professional, 3. Financial, and 4. Intellectual. A teacher either is gaining capital or spending it. However, I wonder if these categories overlap too much. Further analysis suggested simplifying the categories into either *sharing* or *acquiring*.

As I reviewed this interview again, I found some areas difficult to categorize because they contained elements of both. Therefore, I considered a third category *transfer*. The concern is that *transfer* is similar to *sharing*. However, I currently think of it as taking experiences and bringing them into the classroom. Yet, this could be a type of *sharing*. I need to see what the data suggests about this method of coding?

Is there a distinction between *sharing* and *transfer*? Maybe a better word would be '*translation*' or '*adaptation*'? How do I differentiate between *transfer* to the classroom and presenting at conferences or professional development offering? Maybe these are manifestations of the same category and I am just seeing dimensions of the category. If *sharing* and *acquiring* are basic concepts, does the balance of these categories change over time for a participant? For instance, do they *acquire* more up front and *spend* more during later involvement with the program? Will the balance between *sharing* and *acquiring* vary for teachers at different stages of their careers?

Appendix E

Exemplifiers of Action

Property	Code	Exemplifier
Dissemination	Content Knowledge	*I spoke to the teachers about my TEA experience and the variety of science conducted aboard the icebreaker.*
	Pedagogical Content Knowledge	*When I presented the information on the penguins I had to emphasize different strategies that I found most effective for different age groups.*
	Resources	*I gave each of the teachers topo[graphic] maps they could use in their classrooms.*
Acquisition	Content Knowledge	*And, then how that amount of daylight would affect your body. I feel that all of that knowledge was all brand new.*
	Pedagogical Content Knowledge	*I learned a great way to teach students how to best present data from the seals.*
	Resources	*At one point she went through all the standards for elementary school and typed them all on one sheet of paper concisely. I refer to them constantly…*
	Vicarious Experience	*After she showed us the conditions and described them – just the physical ordeal of it all. I cannot imagine that. That was very impressive.*
Synthesis	Content Knowledge	*We worked to set up a two and a half day conference for teachers to share knowledge with each other…that centered around polar sciences.*
	Pedagogical Content Knowledge	*I never used graph predictions before working with him. Combining that with the data from the field allowed me to present the material much better.*
	Resources	*[We] were preparing for our presentation and we got some stuff/materials together. That had a huge folder… and information to take home with them.*
	Curriculum	*One of the teachers brought in this cookbook style lab and ramped it up to be more inquiry based. I ended up using that in my own classroom.*

Appendix F

Exemplifiers of Interaction

Property	Code	Exemplifier
Authoritative	View Point	*Sometimes she had done the activity and she would say, 'here, take my materials and try it. Don't go by anything else.'*
	Access	*The presentation was interesting but I had no opportunity to ask follow up questions later in the year.*
	Focus	*I think it was of course frustrating because we had so many activities because we wanted to cover a lot of information that there wasn't sufficient time.*
	Transfer	*I know that she was working for a scientist. That she was doing some samples of water. I don't know all of the details of exactly what she did.*
	Ownership	*We were required to sit in on the presentation as part of the in-service program. I had no choice.*
Dialogic	View Point	*…interacting with the different teacher at the program and seeing some of the things that they do and – especially in different class areas.*
	Access	*Or, I need to ask how I should present this. I always have someone I can call on.*
	Focus	*…it was pleasant… to work with others teacher and the scientists simultaneously so we could develop things that were really meaningful.*
	Transfer	*We came up with several activities like this for use in the classroom…*
	Ownership	*Preparing the presentation that we proposed was a motivating factor. As a stakeholder, I wanted to make sure it was meaningful to those who attended.*

Appendix G

Exemplifiers of Engagement Results

Property	Code	Exemplifier
Teacher Change	Content Knowledge	*Now I am more knowledgeable in the area so I am comfortable talking with them about their field versus mine.*
	Pedagogical Content Knowledge	*Better labs I would say because a lot of what we did was take old labs, ones I've been using for fifteen years, and seeing what newer teachers were doing.*
	Enthusiasm	*After a meeting or get together it would help you get more energetic about what you were doing.*
	Perspective	*I think that showing that this is what a group of eighth graders can do, given the opportunity, they can do this kind of thing.*

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