A COLLABORATIVE DIAGONAL LEARNING NETWORK:
THE ROLE OF FORMAL AND INFORMAL PROFESSIONAL DEVELOPMENT
IN ELEMENTARY SCIENCE REFORM

by

Natasha Anika Cooke-Nieves

Dissertation Committee:
Professor Felicia M. Mensah, Sponsor
Professor O. Roger Anderson

Approved by the Committee on the Degree of Doctor of Education

Date________________________________

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ABSTRACT

A COLLABORATIVE DIAGONAL LEARNING NETWORK:

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Natasha Anika Cooke-Nieves

Science education research has consistently shown that elementary teachers have a low self-efficacy and background knowledge to teach science. When they teach science, there is a lack of field experiences and inquiry-based instruction at the elementary level due to limited resources, both material and pedagogical.

This study focused on an analysis of a professional development (PD) model designed by the author known as the Collaborative Diagonal Learning Network (CDLN). The purpose of this study was to examine elementary school teacher participants' pedagogical content knowledge related to their experiences in a CDLN model. The CDLN model taught formal and informal instruction using a science coach and an informal educational institution. Another purpose for this research included a theoretical analysis of the CDLN model to see if its design enabled teachers to expand their resource knowledge of available science education materials.

The four-month-long study used qualitative data obtained during an in-service professional development program facilitated by a science coach and educators from a large natural history museum. Using case study as the research design, four elementary school teachers were asked to evaluate the effectiveness of their science coach and museum educator workshop sessions. During the duration of this study, semi-structured individual/group interviews and open-ended pre/post PD questionnaires were used. Other data sources included researcher field notes from lesson observations, museum field trips, audio-recorded workshop sessions, email correspondence, and teacher-created artifacts. The data were analyzed using a constructivist grounded theory approach. Themes that emerged included increased self-efficacy; increased pedagogical content knowledge; increased knowledge of museum education resources and access; creation of a professional learning community; and increased knowledge of science notebooking.

Implications for formal and informal professional development in elementary science reform are offered. It is suggested that researchers investigate collaborative coaching through the lenses of organizational learning network theory, and develop professional learning communities with formal and informal educators; and that professional developers in city school systems and informal science institutions work in concert to produce more effective elementary teachers who not only love science but love teaching it.

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N. A. C.-N.

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INTRODUCTION

Statement of Purpose

This study sought to examine the role that two, usually considered separate, professional development models—formal and informal—play in constructing the pedagogical content knowledge and resource awareness of elementary teachers in science. Science education research has produced a vast array of findings citing effective professional development programs that have one or more of the following components: an informal science institution, college/university or scientist that may only be organized by a district science supervisor or museum educator (Astor-Jack, McCallie, & Balcerzak, 2007; Melber & Cox-Peterson, 2005; Rivera Maulucci & Brotman, 2010; Tanner, Chatman, & Allen, 2003). Other studies pay particular attention to content knowledge, teaching skills, teacher's perceptions, museum trip preparation, curricular alignment, and/or student learning outcomes (Bell & Gilbert, 1994; Connolly, Groome, Sheppard, & Stroud, 2006; Gerber, Cavallo, & Marek, 2001; Kisiel, 2006; Rivera Maulucci & Brotman, 2010; Roth, 1998; Supovitz & Turner, 2000; Tal & Steiner, 2006). Yet, many professional development programs and parallel research still fail to address the dual role that a science coach and a museum educator can perform in developing a teacher's "personal bag of tricks" when teaching science. Furthermore, the literature points out that most elementary school teachers lack a strong understanding of science (Anderson & Mitchener, 1994; Lederman, 1992) because of few or inadequate science education experiences (Anderson & Mitchener, 1994; Lederman, 1992; Tilgner, 1990). Understanding elementary school teachers' belief systems as well as their classroom practices when teaching science is essential to implement reform efforts that boost the amount of time science is taught, and taught well, throughout a child's PreK-5th grade education.

National educational reform efforts (American Association for the Advancement of Science [AAAS], 1990; National Research Council [NRC], 1996; National Science Teachers Association [NSTA], 2006) suggest that teachers need opportunities to engage with other professionals in teacher-centered professional development programs. Both the personal and professional growth of the teacher must be addressed when considering a teacher's role in the contextual classroom, and professional development is a crucial component in shaping this growth (Moore, 2008a). National reform standards state that professional development needs to be longer than a one-shot workshop and should be focused on pedagogy as well as on content (No Child Left Behind [NCLB], 2001). As teaching practices continue to evolve in the United States and common core standards are implemented, professional developers have the added responsibility of rethinking which providers they can collaborate with in order to produce highly-qualified teachers for elementary classrooms.

Elementary teachers need professional development in science-specific pedagogy to construct deeper meanings of the subject and to learn novel classroom strategies for use in teaching science to their students. The recent urgency for college and career readiness skills for tomorrow's scientists and the general need for increased literacy in science place added demands on producing the best and brightest teachers. This study addresses the call for highly-qualified science teachers at the foundation of our educational system—the elementary school—through a dual network of formal and informal providers. By creating collaboration between an in-house science coach and off-site museum educators, this study sought to investigate whether the science teaching skills and awareness of museum resources of four elementary teachers improved over a period of four months.

Factors That Determined the Origin of This Study

The Science Core Curriculum

The Department of Education (DOE) in the city where the study's school site is located conducted a major overhaul of the materials that teachers use to teach science. During the 2007 school year, K-8 schools were given the option of using their curriculum material allotment to purchase a text, kit-based or combination program through the $60 million K-8 Science Core Curriculum Initiative that was implemented over the following two years. Grades 3, 4, and 6 began to use their science program materials in 2007; Grades 5, 7, and 8 in 2008; and Grades K, 1, and 2 in 2009 (NYC Department of Education, 2008). Professional development (PD) was budgeted for this Initiative through city funds; however, not all administrators or teachers knew about the PD opportunities, were given the time to attend them or were allowed to present what they learned if they had gone. For this reason, thousands of teachers were given brand new DOE-approved science instructional materials with no training on how to use them.

All approved program options met the State science standards and the city's new K-8 Science Scope and Sequence for curriculum and instruction. In addition, the city included teacher-selected relevant trade books and developed daily lesson plans for each grade using the three approved programs for integration into existing science curricula. As of 2009, along with web-based resources that include PD videos, teacher/student book editions, lesson plans, assessment ideas, and student games, teachers have a plethora of tools at their fingertips—whether they know it or not.

How I Came to This Study

I entered teaching via an alternative route with a major in biopsychology and absolutely no experience teaching a class. My job was daunting, to say the least, with a B.A. and no certification, I was hired in 1997 as a science cluster teacher at a public elementary school where I taught general science to 400 students ranging in grades 2-6. I moonlighted in a Master's program studying elementary science education and attended every workshop and institute the teachers' union or informal institutions offered. At first, I went for the sake of gaining "new teacher training hours" and then continued out of plain curiosity and a thirst for knowledge. As I was given more information about innovative science teaching methods, I began to see the true value of professional development. When I became a National Board Certified Teacher, I also saw the value of action research and the self-actualization of seeing oneself become a so-called highly-qualified teacher.

During the summer of 2004, I applied for and was accepted into the supervisory cohort of the TRUST (Teacher Renewal for Urban Science Teaching) Institute at the American Museum of Natural History (AMNH). TRUST is a grant-funded professional development program that supports supervisors and teachers in two individual cohorts in order to strengthen their Biology, Earth, and Space science content knowledge, as well as prepare them to use Museum resources and exhibits to engage their teachers and students, respectively. In this two-week professional development Institute, both cohorts deepened not only their understanding of content knowledge, but also their pedagogy by engaging with AMNH scientists and curators, taking behind-the-scene tours, and learning about available print and digital resources. After 10 years of teaching elementary science to children, I shifted from being a science cluster teacher to an in-house science coach at the same public elementary school. As a science teacher leader, I returned to the school in September 2004 with a renewed energy to inform all teachers I assist of the enormous number of resources and curriculum-aligned dioramas and exhibits that AMNH has to offer teachers and students.

As an in-house science coach, I met with teachers one-on-one, in a group, and as an entire staff. For three years, I performed demo lessons, observed teaching, updated teachers on current science education issues, and conducted workshops on how to teach science to elementary students. In 2008, my job position changed from in-house science coach to network-level coach. I currently serve as the instructional specialist for science and math for 26 public schools servicing mostly Title I PreK-12 students in Brooklyn and Queens, New York. My duties remain relatively the same, but encompass a wide range of in-service teachers and delve more deeply into the art of teaching in general and, specifically, the art of teaching science effectively and passionately. I encounter teachers at varying levels of their career—veteran, novice, elementary, high school—some with science content knowledge and poor teaching skills, some with no science content knowledge and great teaching skills. However, the job I face daily is to help all teachers achieve a level of science content knowledge and teaching skills that will enable their students to develop a love of learning science in school and to question the science around them in the real world. In short, this new title and position inspired this research topic.

This research examines the effect that a Collaborative Diagonal Learning Network (CDLN) has on the knowledge acquisition of classroom teachers in elementary science reform. The professional development (PD) occurred in a large urban elementary school facilitated by its science coach and in an outside informal science institution facilitated by museum educators. The pedagogical content knowledge of elementary teachers is assessed and used as a measure of the effect that "diagonal learning" elicits.

The Collaborative Diagonal Learning Network (CDLN) Model

The Collaborative Diagonal Learning Network (CDLN) is a researcher-coined term used in this study that identifies the link that can be established between formal and informal experts in the field in order to develop the pedagogical content knowledge of teachers in science (in this case, at the elementary level). The CDLN model was formulated from the findings of an earlier pilot study related to the current research. The pilot study (Cooke & Moore Mensah, 2009) involved one 4th grade teacher who paradoxically had a high level of science content knowledge but who had a strong dislike for teaching science; the dislike was in fact so strong that I, as the in-house science coach at the time, conducted demo lessons more frequently in his class than any other class in the school. Consequently, during the pilot study, I noticed that he was already receiving professional development from a top-down approach (i.e., vertical learning, Van der Krogt, 1998): moving from the principal's plan, to my coaching, and to his execution of lessons. He was also receiving professional advice across the grade from his fellow colleagues (i.e., horizontal learning, Van der Krogt, 1998) through common grade-level meetings. Therefore, I decided to add a new dimension to his formalized PD: I organized a full-day PD session for the elementary teachers at my school and later coordinated a grade-level trip to the American Museum of Natural History (AMNH). Through a four-month cycle of two types of PD, I saw all aspects linking through a constructivist grounded theory (Charmaz, 2006; Strauss & Corbin, 1998) analysis of the data. Hence, the CDLN model was developed as a tentative theory, waiting to be tested, modified, and grounded in participants, views from in the field. The following diagram (Figure 1.1) shows an abstract schema visualizing the theory into three distinct interactions.

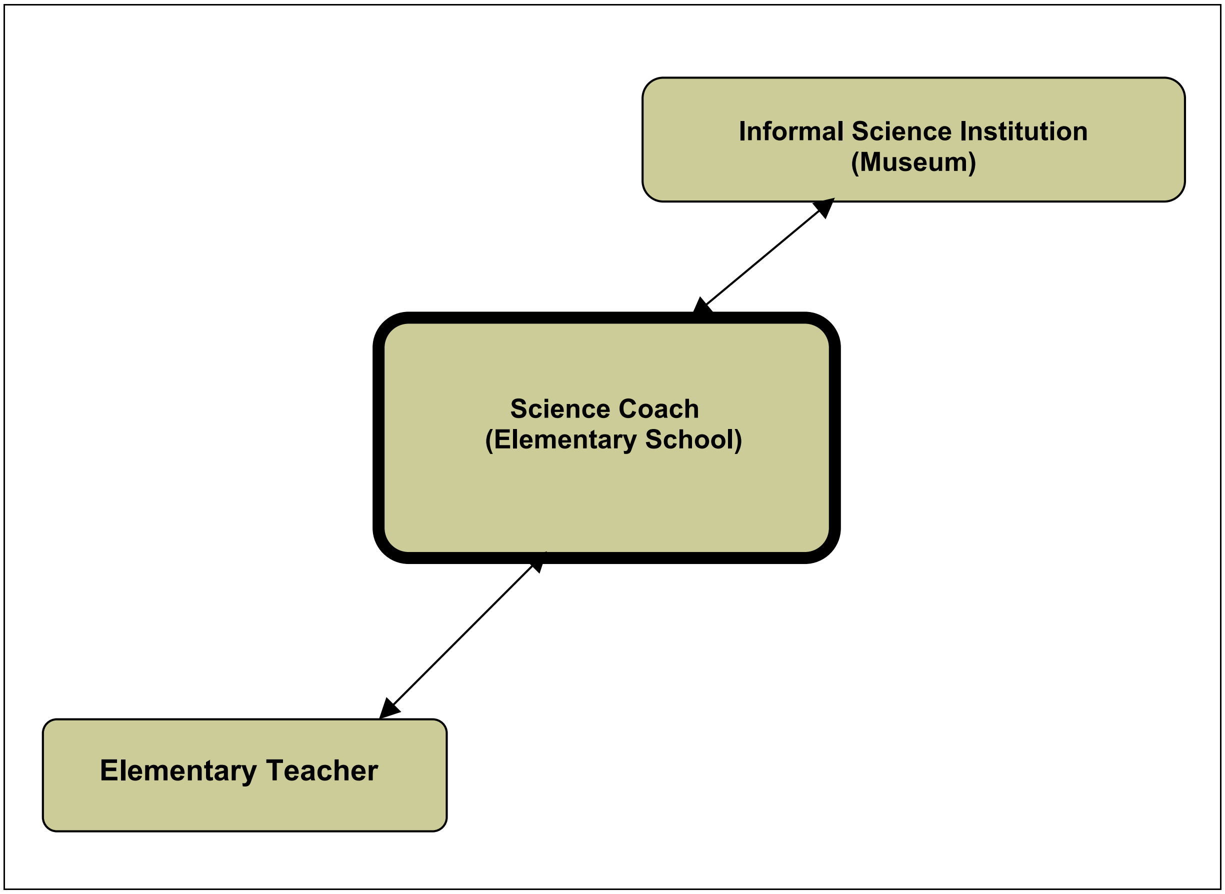


Figure 1.1: Collaborative Diagonal Learning Network (CDLN)—Theoretical Model for Interrelationship with Formal and Informal PD Providers Formulated from Pilot Study

The goal of the CDLN is to serve as a program model for professional development in elementary science reform. The CDLN includes a direct and sustained relationship between the school's science coach through in-house workshops, demonstration lessons, teacher observations, and mini-institutes at an informal institution. Through a summer institute completed at the AMNH, the science coach/researcher involved in this study established a school-to-community partnership with its educators that provides free resources and mechanisms where learning can occur in a nurturing environment.

Research Questions

Using the new model of the Collaborative Diagonal Learning Network, I examined the role of formal and informal professional development in elementary science reform to study its effect on teachers' pedagogical content knowledge. I was curious to learn if novice elementary teachers increased their pedagogical content knowledge (PCK) (Shulman, 1986), identified through instruction in hands-on science coaching and museum-led workshops. The four-month-long study investigated three aspects of professional development: (1) the effect of the science coach; (2) the effect of the informal science institution; and (3) the diagonal link that exists between the coach and the informal institution as a context for learning and teacher development in a new reform effort for professional development.

The overall research questions and sub-questions are:

1. How does the Collaborative Diagonal Learning Network (CDLN) model enhance elementary teachers' acquisition of pedagogical content knowledge (PCK)?
    a. How does the *science coach* enhance elementary teachers' acquisition of PCK?
    b. How do *museum-based workshops* enhance elementary teachers' acquisition of PCK?

   c. How do the *science coach and museum-based workshops* enhance elementary teachers' acquisition of PCK?

2. How does the CDLN model enhance elementary teachers' awareness and practical use of informal science centers?
   a. In what ways does *science coach mentoring* enhance elementary teachers' awareness and practical use of informal science centers?
   b. In what ways do *museum-based workshops* enhance elementary teachers' awareness and practical use of informal science centers?
   c. In what ways do the *science coach and museum-based workshops* enhance elementary teachers' awareness and practical use of informal science centers?

The professional development (PD) activities reported in Melber and Cox-Peterson (2005) as well as in this study represent an integrated approach—combining content and instruction with actual scientific materials and views voiced by museum educators in informal discussions. Moreover, the collaborative network in this study included the following elements of a successful science PD program: (a) a focus on academic content, (b) hands-on experiences and active learning, and (c) clear integration into the classroom (Garet, Porter, Desimone, Birman, & Yoon, 2001, as cited in Melber & Cox-Peterson, 2005).

Overview of Chapters

In the next chapter (Chapter II), I review background literature relevant to this study overall and present the theoretical framework for the study. The literature review discusses scholarship from the field of science education about the relationship between professional development in general, and paying particular attention to coaching and workshops that take place in formal (school) and informal (science institution) settings. It also addresses literature on pedagogical content knowledge specifically, including a discussion of the empirical literature on the history of elementary teachers' teaching subject-specific content. The theoretical framework outlines ideas about teacher learning from a diagonal network and the core curriculum that underlie this study.

Chapter III explains in detail the methods and methodology for this study. This qualitative study drew on aspects of a grounded theory research approach (Strauss & Corbin, 1998). The researcher's role was that of a participant observer, as explained by Guba and Lincoln (1981), and addressed in this chapter. The study was conducted at a public elementary school in a very large urban city over the course of four months, with four teachers as the primary participants and three facilitators as the secondary participants. Primary sources of data included audio-recorded workshop sessions, questionnaires, and interviews with these teachers; secondary data sources included participant observations and field notes. This chapter also explains data analysis, validity, and ethical considerations.

The findings of this dissertation are written in the format of three publishable papers (Chapters IV, V, and VI) with no reference sections provided. The first findings paper (Chapter IV) addresses the first research question and examines how the various entities of the Collaborative Diagonal Learning Network Model (CDLN) model―science coach, museum or both―are able to enhance teachers' acquisition of pedagogical content knowledge (see Table 1.1). The paper uses an authentic and situated learning perspective (Brown, Collins, & Duguid, 1989; Lave & Wenger, 1991) of teacher professional development through an apprenticeship model. It also examines how different venues of teacher learning can interact to bring about the self-efficacy (Bandura, 1997) and pedagogical content knowledge (Shulman, 1986) of elementary teachers.

The second paper (Chapter V) addresses the second research question, which explores how the CDLN model enhances teachers' awareness and practical use of informal science institutions through different venues (see Table 1.1). The unofficial development of a professional learning community is the theoretical basis of a conscious and informed teaching professional. By taking advantage of nearby educational resources, coactivation triggers the use of social and cultural capital to educate urban youth.

A case study of one teacher that addresses the first research question is discussed in the third paper (Chapter VI). In this paper, the teacher reveals a remarkable change she underwent from the beginning of the study (see Table 1.1). Drawing on ethnographic participant observation during the study as well as artifacts and field notes, this paper describes the positive influence that the CDLN had on one participant both in and out of the classroom.

Finally, Chapter VII reiterates the overall findings of the dissertation and discusses significant implications for science education as well as for organizational learning theory researchers, museum educators, professional developers, policymakers, and school administrators.

Table 1.1. *Chapters That Address the Research Questions of the Overall Study*

Research Questions	Chapters Addressing Research Questions
(1) How does the Collaborative Diagonal Learning Network (CDLN) model enhance elementary teachers' acquisition of pedagogical content knowledge (PCK)? ▪How does the *science coach* enhance elementary teachers' acquisition of PCK? ▪How do *museum-based workshops* enhance elementary teachers' acquisition of PCK? ▪How do the *science coach and museum-based workshops* enhance elementary teachers' acquisition of PCK?	Ch. IV Ch. VI
(2) How does the CDLN model enhance elementary teachers' awareness and practical use of informal science centers? ▪In what ways does *science coach mentoring* enhance elementary teachers' awareness and practical use of informal science centers? ▪In what ways do *museum-based workshops* enhance elementary teachers' awareness and practical use of informal science centers? ▪In what ways do the *science coach and museum-based workshops* enhance elementary teachers' awareness and practical use of informal science centers?	Ch. V

Chapter II

LITERATURE REVIEW

Professional Development

Professional development is defined as:

> …the actual learning opportunities which teachers engage in—their time and place, content and pedagogy, sponsorship and purpose. Professional development also refers to the learning that may occur when teachers participate in those activities. From this perspective, professional development means transformations in teachers' knowledge, understandings, skills, and commitments, in what they know and what they are able to do in their individual practice as well as in their shared responsibilities. (Feiman-Nemser, 2001, p. 1038)

Professional development is (or should be) construed as a lifelong learning opportunity. As an old idiom states, "every day you learn something new," and professional development can be that set of learning opportunities and the actual construction of learning by teachers. As stated by Feiman-Nemser states, "professional development means transformations in teacher's knowledge, understandings, skills, and commitments, in what they know and what they are able to do in their individual practice as well as in their shared responsibilities" (p. 1038). The ultimate goal in professional development (PD) is to better oneself to improve student learning. For example, Feiman-Nemser found three central themes in current discussions on PD reform: (1) serious ongoing dialogue; (2) dialogue taking place within a community of practice; and (3) dialogue focusing on teaching, learning, science subject matter, and students. Hence, professional development connects teachers' learning to student understanding and ultimately affects elementary science reform by changing a school's culture.

Reform movements have transformed PD from traditional and outdated formal in-service workshops and college coursework to a meaningful learning practice. In this educational context, a meaningful learning practice translates into PD sessions including innovative strategies, classroom activities, materials management, pedagogy, and current research to make workshops a vital and relevant training for their teacher participants. Historically, PD was usually of short duration because of funding, with little time to follow up or evaluate the session. Professional development has been studied in terms of its quality of content, process, strategies, and context. Loucks-Horsley and Matsumoto (1999, see Table 2.1) identified 15 characteristics of effective professional development for math and science teachers. The strategies are summarized into five major categories: immersion, curriculum, examining practice, collaborative work, and vehicles/ mechanisms (Table 2.1).

Briefly, the first strategy, *immersion*, occurs when teachers are actually doing scientific inquiry (e.g., summer research in a laboratory); *curriculum* strategies involve teachers implementing, adapting or developing curriculum materials; *examining practice* occurs when the PD is concentrated and teachers act as researchers to look at their own practice; *collaborative work,* includes professional networks in and out of school (e.g., coaching/mentoring and partnerships with scientists); and lastly, *vehicles and mechanisms* are structures for which PD is enacted and staff developers are trained.

Table 2.1. *Professional Development Strategies*

Immersion	Immersion into Inquiry and Problem-Solving Immersion into the World of Science and Mathematics
Curriculum	Curriculum Implementation Curriculum Replacement Units Curriculum Development/Adaptation
Examining Practice	Action Research Case Discussions Examining Student Work and Thinking and Scoring Assessments
Collaborative Work	Study Groups Coaching and Mentoring Partnerships Professional Networks
Vehicles/Mechanisms	Workshops, Institutes, Courses, Seminars Technology for Professional Learning Developing Professional Developers

Effective professional development has also been shown to advance teacher application of new skills. When the three phases of PD (planning, training, and follow-up) are incorporated, a teacher-based change model is usually successful (Haney & Lumpe, 1995). Using all three phases, a continuous model of PD versus single-training sessions over a long duration enhances the professional knowledge of teachers in science (Koch & Appleton, 2007).

Taking all these features into account, professional development has evolved over the last 50 years to include effective learning environments in which these categories can develop and thrive. According to Loucks-Horsley and Matsumoto (1999), four characteristics of effective learning environments provide a base for the certain kinds of learning teachers require to jumpstart science reform. These four professional learning environments are: *learner-centered,* which is the starting point; *knowledge-centered*, where teachers are allowed activities for conceptual change; *assessment-centered*, where teachers receive feedback and amend their practice; and *community-centered*, where teachers are given time to work together and learn from each other.

In a typical implementation, these learning environments may be used consecutively or in combination with each other. For example, Loucks-Horsley and Matsumoto (1999) point out that a workshop where teachers learn how to use new curriculum materials can be followed by continuous coaching in their classrooms. Accordingly, an organizational culture of support must also exist for PD to be made a priority and a success. As accountability increases because of the No Child Left Behind (NCLB) Act and state/city-mandated annual school quality reviews, PD initiatives encouraging improved teacher and student learning are being viewed more closely for dissemination. One model gaining wide support is the focus of this study: a collaborative learning environment (National Commission on Mathematics and Science Teaching, [NCMST], 2000).

A collaborative learning environment is established when teachers, administrators, and community organizations all commit to a common vision and standards for science learning that meets the diverse needs of students. By merging the scientific knowledge of each stakeholder, each participant brings a certain level of expertise and resources to support a meaningful learning practice. The collaborative structures are based on the assumption that the quality and effectiveness of science teaching are not the sole responsibilities of the teacher, but of the larger community extending partnerships to scientists and other professional networks (i.e., business, industry, science centers) (Loucks-Horsley, 2003).

Formal Science PD (Coach Mentoring Model)

In this study, the term "formal" is used when referring to the place (K-6 school) or person (science coach) conducting the professional development. Formal professional development that is sponsored by city agencies, such as schools and districts, usually lack evidence of teachers' professional growth. City agencies find a need to hold a program accountable in terms of student progress rather than teacher progress. However, as Loucks-Horsley and Matsumoto (1999) note, research on teachers does not necessarily have to be accompanied by an assessment of the performance of the teachers' students. They argue that "fixating" on student learning ignores other critical outcomes. In the present study, I examine the deep underlying characteristics of formal PD in a school setting by providing a template for the implementation of a coaching model to observe teacher growth.

A coach in sports is needed to train, prepare, and instruct the team for a game. A coach in education is also needed to train, prepare, and instruct teachers for a lesson. A teacher who is a veteran in years can still be a novice teacher in content. This is true of elementary teachers, especially when teaching science. An apprentice should work side by side with a master in the traditional model of learning a craft. Authentic learning takes place within a culture of learners acting in a realistic situation (Lave & Wenger, 1991). The members and tools within these authentic environments provide the resources for learning, making it real or truly authentic. As Brown, Collins, and Duguid (1989) suggest, learning in this type of context can be construed as "situated" within an authentic setting (p. 36). The most effective ways of learning about teaching (and learning in general) are often not quantifiable and teachable, but only can be understood through actual practice (Roth, 1998).

The authentic setting where learning takes place must be taken into consideration. Apprentices complete easier tasks in order to help them understand and learn the skills they need to perform more challenging tasks, all while receiving coaching from the master (Lave & Wegner, 1991). The most successful way to train new teachers is through an apprenticeship model where learners work alongside experienced masters. Experienced teachers cannot always articulate their intrinsic classroom actions (Roth, 1998), yet many skills that a teacher needs are cognitive and not easily taught in a step-by-step procedure or even perhaps understood by most observers (mainly the administrators evaluating them). Therefore, it is important for an elementary teacher to have a science coach who is a master of the subject area and who can explain the cognitive skills and teaching processes necessary for the novice apprentice teacher to reach a mastery level of science education.

Cognitive apprenticeship is a model that can be applied to the study of professional development as well. Collins, Brown, and Holum (1991) describe two of the major teaching methods of cognitive apprenticeship: modeling and coaching. Through these experiences, an apprentice teacher can observe a coach modeling a lesson or build upon the pedagogical skills needed to teach effectively. The master teacher or coach can offer tips and give feedback to bring the apprentice teacher closer to professional mastery and a sense of self-confidence. The learning model of cognitive apprenticeship provides an excellent context for authentic learning to occur within in-service staff development.

This study focuses on elementary science mentoring with the goals of developing new knowledge and skills, a deeper understanding of curriculum content and pedagogy, increased motivation/attitude toward science teaching, and new curricular ideas for teachers (Koch & Appleton, 2007). An earlier review of mentoring studies by Joyce and Showers (1980) showed PD program attributes as individual components in teacher training:

1. Presentation of theory or description of skill or strategy,
2. Modeling or demonstration of skills or models of teaching,
3. Practice in simulated and classroom settings,
4. Structured and open-ended feedback (provision of information about performance), [and]
5. Coaching for application (hands-on, in-classroom assistance with the transfer of skills and strategies to the classroom). (p. 380)

These aspects of training were incorporated into the mentor model used by Koch and Appleton (2007) as well as to the coaching model in this study. By using continuous professional development in which the coach planned, trained, and offered follow-up to the teachers, it was possible to evaluate the acquisition of science PCK by the elementary teacher in this study.

<u>Informal Science PD</u>

When referring to the professional development implemented in this study, I adopted the definition of the term “informal” that Bevan, Dillon, Hein, Macdonald, Michalchik, Miller, Root, Rudder, Xanthoudaki, and Yoon (2010) use when defining informal learning organizations. These organizations could be either public educational facilities (i.e., libraries, afterschool programs) or “science-rich cultural institutions” (i.e., museums, zoos, aquaria) (p. 12). In this study, the latter designation is used: informal science professional development refers to PD conducted at a museum or by a museum educator.

Informal educational experiences have been shown to increase teachers’ conceptual understanding, self-confidence, and even student knowledge when a teacher participates in pre-museum trip training (Melber & Cox-Peterson, 2005; Rivera Maulucci & Brotman, 2010). Informal science institutions also offer teachers the resources and professional assistance that are sometimes needed for those working in urban schools that face more challenges with a limited availability of materials and inadequate PD (Melber & Cox-Peterson, 2005).

Literature that addresses informal science institutions indicates that they have a long history of offering special programs for teachers at parks, aquaria, zoos, or museums (Phillips, Finkelstein, & Weaver-Freichs, 2007). Beyond the typical one-day field trip, informal science institutions such as museums increase the amount of time teachers can be engaged in a curriculum topic by deepening the rigor and exposure to non-traditional learning experiences. Museums are just one type of science institution among many within the realm of informal education, yet their impact is at the center of science teaching and learning outside of schools.

Museums are able to offer teachers unique ways to deepen their content knowledge and unique means to develop alternatives to studying the nature of science (NSTA, 1999). To examine this point, Phillips, Finkelstein, and Weaver-Freichs, 2007) surveyed 475 informal science institutions (ISIs) that provide support for K-12 science education, particularly in the area of teacher professional development, in the form of programs for schools and teachers beyond one-day field trips. Only 21% of the ISIs offered programs that provide "teacher coaching and classroom support (demonstrations, shared teaching, and/or other forms of in-school support by staff or teacher interns from your institution)" (Phillips, Finkelstein, & Weaver-Freichs, 2007, p. 1495) and 45% of the ISIs offered collaboratives or partnerships (with businesses, industry, colleges, universities, schools or some combination thereof). Overall, most ISIs only provided service for experienced/veteran upper elementary teachers with at least five years of teaching experience. These findings are a reminder that more PD programs should be intended for novice teachers with little or no pedagogical content knowledge in science (Meyer, 2004). The PD programs surveyed in Phillips, Finkelstein, and Weaver-Freichs (2007) revealed that content knowledge was their first goal, whereas pedagogy and how to use ISI resources came in as second and third goals, respectively. No combination of the three was even given as a possible survey response.

There is a gap in the literature focusing on the link between informal and formal teacher professional development. "In addition, notably absent from these ISI programs was a connection with reform efforts dealing with bridging informal learning environments and the formal education system, such as curriculum implementation"

(Phillips, Finkelstein, & Weaver-Freichs, 2007, p. 1505). The researchers also stated that "ISIs may be missing key opportunities to partner with schools" (p. 1505). Hence, the present study sought to enhance the research base on this topic and allow for missed opportunities for school/museum partnerships inside elementary school classrooms. ISIs are being underutilized by teachers and schools because they have not been proactive or consistent in supporting their alignment with current K-12 district-level reform efforts (Phillips, Finkelstein, & Weaver-Freichs, 2007). The structure of the present study and the CDLN model under investigation hopes to address the potential for ISIs, such as museums, to bridge school science education reform with the development of teacher-centered pedagogy.

Science Education Reform for Elementary Science Education

Ever since the University of Chicago Laboratory School, originally founded by John Dewey in 1896 introduced practical science methods such as shop work and cooking at the elementary level, it has been clear that children need hands-on experiments to integrate into their own daily lives (Buxton & Provenzo, 2007; Dewey, 1990). Dewey felt that every child could transfer what he or she learns from school to home and home to school. He wanted to see in-school connections to museums, libraries, universities, research laboratories, textile industries, banks, gardens, and parks. Dewey (1990) envisioned children having a natural relation to the environment and to their social and future professional lives. However, the realization of inquiry-based science for elementary children did not take precedence in government and policy until the U.S. failed to launch the first spacecraft 61 years after Dewey founded the Lab School.

As a result, three programs were created for the elementary school with financial support from the National Science Foundation (NSF): Science―A Process Approach (SAPA-1967), Elementary Science Study (ESS-1969), and Science Curriculum Improvement Study (SCIS-1970), all part of the "ABC" curricula. In the mid-1970s, NSF conducted a study on elementary programs and found that the three most popular— SAPA, ESS, and SCIS―were being used by about one-third of the elementary school districts in the nation. Quick (1978), who examined the curriculum reform movement, concluded that one major innovation was the inclusion of an activity-oriented method to science instruction. For example, there was an increase in the number of elementary programs (27 by 1975). Although only two of them were based on science manipulatives, the others were "text-only" (12/27) or "textbook with lab" (13/27) (DeBoer, 1991, p. 169). Quick concluded that federal policy initiatives saw a renewed interest in elementary science, but science publishing companies lacked the insight to focus solely on activity and discovery-oriented programs. Hurd (1970) also summarized his analysis of the curriculum reform projects into 14 strengths and 13 weaknesses. One weakness specifically stated that the new programs did not do enough to motivate children to study science because little was incorporated into their daily lives, as Dewey had proposed in the early 1900s (as cited in DeBoer, 1991).

Therefore, after the nation witnessed the Sputnik-era and Cold War educational reforms failed to produce the next generation of highly-trained scientists, the nation lost faith in the science educational system. For instance, the results from the Third International Mathematics and Science Study (TIMSS) in 1995, which evaluated 41 nations, showed

> children in the United States were among the leaders in the fourth-grade assessment, but by high school graduation were almost last. Here at home, the National Assessment of Educational Progress [NAEP, 'the nation's report card'] substantiates our students' poor performance (NCMST, 2000, p. 4). In 1996, NAEP results showed that more than one-third of all U.S. students in grades 4, 8, and 12 scored below the basic level in mathematics and science. (NCMST, 2000)

Since the international and national assessments of the 1990s proved that the U.S. was lacking in science education—not just for the small subset of the population slated to be scientists, but for all K-12 students, a shift has occurred in scientific literacy. At the forefront of the new science education reform movements is the American Association for the Advancement of Science (AAAS), which published of *Science for All Americans* (1990) and *Benchmarks for Scientific Literacy* (1993), both components of a landmark endeavor entitled Project 2061 (i.e., the year Haley's Comet returns to Earth). Then in 1996, based on the AAAS documents and the NSTA, the National Research Council (NRC) published the *National Science Education Standards* (NSES) which influenced other subsequent state and local district standards. More recently, it published *Inquiry and the National Science Education Standards: A Guide for Teaching and Learning* (2000). The National Science Resources Center (NSRC) reform model also provides a new direction for the elementary science education reform movement of the last few decades (NSRC, 1997).

> The NSRC model for reform provides guidance on how to achieve these goals. Of particular importance is the development of a shared vision of

> teaching science through inquiry and the adoption of an implementation strategy that focuses on the five key elements of reform—curriculum design, *professional development*, science materials support, assessment, and administrative and community support. (p. 192)

The focus of elementary science reform has shifted back to teachers—how informed are teachers to implement newly-designed curricula into their classroom and find the support they need to sustain it. van Driel, Beijaard, and Verloop (2001) discuss current reforms in science education from the perspective of developing a teacher's practical knowledge. Practical knowledge is defined as the knowledge and beliefs a teacher has about his or her own practice, and is mainly a result of teaching experiences in the classroom. The researchers believe that teachers' practical knowledge is a major factor in the way they react to educational change. Traditionally, science has been taught lecture-style to convey content and technical training for practicality. Science as a discipline has oftentimes been shown as a rigid body of facts, rules, and theories. However, this outdated way of teaching does not adequately prepare future citizens for careers in Science Technology Engineering Mathematics or STEM (NCTAF, 2003). Undergraduate science courses, teacher preparation programs, and in-service activities frequently stress technical skills and content rather than reasoning and decision-making skills which are necessary for inquiry and the real world (NRC, 2000). The culture of "school science" has affected professional development by restricting its delivery to teachers. To change this state of affairs, the aforementioned series of publications and policy (AAAS, 1990, 1993; NRC, 1996; National Science Resource Center [NSRC], 1997) have sponsored a nation-wide reform in science education.

Influence of Informal Education as an Approach to PD and Teacher Learning

As stated in the National Science Education Standards (NSES), teachers should have the opportunity to engage in an analysis of the three components of pedagogical content knowledge (PCK)—science, learning, and pedagogy through extensive collaboration. Schools can work with “science-rich centers” to organize PD activities with teachers. Another connection between science teaching and learning, as defined in standard B of the NSES Standards for professional development, is accomplished “through thoughtful practice in field experiences, team teaching, collaborative research, and peer coaching” (NRC, 1996, p. 67).

Teachers require learning opportunities from local expertise as well, forging a collective wisdom between teachers and outside educators. Learning opportunities can exist both inside and outside schools. Lieberman and Grolnick (1996) found evidence which supports that outside learning opportunities act as a catalyst for inside learning opportunities. For example, in their study, educational reform networks took part in courses and institutes outside the school. These experiences allowed teacher participants to meet members from outside their school and to build personal-professional relationships. Thus, teachers need access to broader communities of discourse, practice, and resources. School/university partnerships, professional organizations, and informal institutions can all serve as part of “educational reform networks” that inform and support teachers in their learning process and work (Feiman-Nemser, 2001; Lieberman & Grolnick, 1996).

The city in which the present study took place is home to nine key research institutions, with close to half a million scientists, and the world's leading cultural informal institutions many of which offer a broad selection of K-12 educational programming. "Yet with the City's large community of working scientists and abundant scientific resources, many of its science teachers struggle to connect their students with the available after-school, summer, and digital learning opportunities" (www.nyas.org).

As stated in the NSTA's (1999) position statement on Informal Science Education, "informal science education generally refers to programs and experiences developed outside the classroom by institutions and organizations that include" but are not limited to: children's and natural history museums, planetariums, zoos, and parks. An informal institution can serve as "the proving ground for curriculum materials." Informal science learning experiences allow teachers' access to scientists, resources, authentic instruction, and a personal and professional boost in their science content repertoire.

In addition, the NSTA's (2006) position statement on Professional Development clearly states that PD for science teachers must include community, scientist, university, and parent partnerships. Informal science organizations are also encouraged to build support for PD that enhances the quality of the program in the community.

A mutualistic relationship needs to exist between the two settings of formal and informal learning environments. Informal settings bring characteristics of self-directed learning, self-assessment, visual tasks, process-oriented real objects, and highly interactive exhibits, to name a few. By contrast, formal settings include elements of didactic interactions, formal assessment, orientation to topics, text-based materials, and more structured learning (Ash & Klein, 2000). The present study shares the vision that these two areas "can inform each other, share expertise, and maximize synergy" (p. 219).

Theoretical Frameworks

The four theoretical frameworks used in this research are constructivist learning theory, pedagogical content knowledge, capital, and organizational learning theory.

Constructivist Learning Theory

In 1978, Vygotsky described the zone of proximal development as the space between unassisted and assisted learning where a learner needs teacher assistance to go to higher levels of understanding. It is the space in which learners construct their own knowledge. However, as O'Loughlin (1992) states, *social constructivism* focuses on a transformation model, where learning occurs because of the cognitive processes that learners use. Hence, learners actively *construct* their own knowledge through group interactions. The theoretical basis of social constructivism stems from the information processing model that examines how learners learn, encode, store, and retrieve meaningful and complex material. It identifies isolated versus interconnected networks of knowledge as ways learners organize discrete and linked facts. It also recognizes that prior knowledge and its organization play a key role in learning. There is a difference between experts (who employ deeper principles) and novices (who employ surface-level features of a topic). Several early application programs of information-processing research sought to enhance learners' learning capacity, observe learning strategies, and address student misconceptions through conceptual change.

Recent formulations of social constructivism highlight the influence of society and the real world on providing shared meaning. Knowledge can be and is based on transference from the classroom to social situations. A teacher's knowledge for content and pedagogy is deeply rooted in teaching contexts where interactions occur between teacher-teacher, teacher-coach, and teacher-museum educator. In this regard, I placed a great emphasis on verbal discourse (i.e., researcher field notes) between all three group social interactions.

The role that individual teachers play allows knowledge to be reflected in their social settings (communities of discourse and context) and interactions (language) which include: (a) content knowledge, pedagogical knowledge, and pedagogical content knowledge; (b) conceptual change; and (c) collaborative learning networks (O'Loughlin, 1992).

Pedagogical Content Knowledge (PCK)

The second theoretical framework coined by Shulman (1986) is *pedagogical content knowledge* or *PCK*, which refers to how teachers teach their subject matter. PCK consists of two key elements: (1) knowledge of subject-matter instructional strategies, and (2) student misconceptions with respect to the subject matter. Content knowledge, or comprehension of the subject matter being taught, and pedagogical knowledge, or the practical know-how of the classroom, define the two key elements that constitutes PCK. PCK is usually based on professional experience rooted in classroom practice; hence, beginning/novice/maverick teachers have little to no PCK at their disposal. In relation to this study, PCK is seen as reaching a mature level of conceptual and practical knowledge

(Shulman, 1986; van Driel, Beijaard, & Verloop, 2001). PCK and its relation to learning from PD will be discussed in further detail in Chapter IV.

Capital

Bourdieu (2011) describes capital as "accumulated labor," and identifies three different types of capital, two of which this research used as its theoretical framework: *cultural capital* and *social capital.* The form of cultural capital that this study addressed appears in an "objectified state, in the form of cultural goods" (p. 84). As an educational investment, museums offer material objects (collection of exhibits, online educational resources) that must be used in accordance with the appropriate grade-level science curriculum. By contrast, social capital is a combination of the norms, structures, and resources linked to a "network of connections" that usually forms membership with a group (Monkman, Ronald, & Theramene, 2005). In this case, social capital was viewed in terms of its conversion from cultural capital with the help of human resource agents (i.e., science coach and museum educators). Monkman, Ronald, and Theramene note that weak ties among relationships within a social network shed light on the ability to gain institutional access. The museum educators in this study serve as strong ties and support mechanisms in an effort to gain social capital. For this reason, this study sought to determine the effects of introducing of public science education resources to teachers that are of value as cultural and social investments.

Organizational Learning Theory

The third theoretical framework stems from *organizational learning theory.* Poell, Chivers, van der Krogt, and Wildemeersch (2000a) note that employees in a work environment process and structure their learning within horizontal, vertical, and external learning networks. The network is a frame of reference that can be used to describe the social framework of any organization where people (or actors, as the authors refer to them) are exchanging information and interacting with one another. The vertical network is more of a top-down approach, whereby rules and regulations are created and the supervision of learners occurs by administrators and specialists in the field. The horizontal network is more "organic," where the actors are working and learning together in a shared group space. In the external network, new techniques are initiated by outside expert players who have added knowledge in their professional field.

Organizational Learning Network Theory and CDLN. In the present study, the term *diagonal learning* was coined based on the horizontal (between colleagues) and vertical (with a field expert) learning frameworks that van Driel, Beijaard, and Verloop (2001) identified. Diagonal learning can be operationally defined as an (elementary) teacher learning (science) from a lead teacher who maintains a connection to an informal educational institution. The lead facilitator is an experienced teacher in his or her field of specialization and may hold a position as the (science) coach, mentor or staff developer. The lead teacher not only preserves the collegial relationship with fellow (pre- or in-service) educators, but also sustains the professional link to an informal learning community (i.e., museum, zoo, park, farm, aquarium) which offers PD, student access, free educational resources, and even membership to teachers.

As van Driel, Beijaard, and Verloop (2001) acknowledge, “multiple strategies of PD are necessary to promote changes in teacher’s knowledge and beliefs” (p. 148). The researchers suggest that teachers have access to materials, opportunities to discuss and reflect on their practice with coaches, and a supportive clinical learning environment. Learning and PD in *collaborative networks* are highlighted as a type of staff development that can stimulate such a process. In networks, they claim, teachers systematically learn from and with each other as peers. In a “horizontal learning” network, PD is organic, and learning occurs between colleagues. In a “vertical learning” network, PD is mechanical and learning occurs with an external expert. The theory that I present in this study is a collaborative “*diagonal* learning” network, where PD is reciprocal and learning occurs between colleagues and science education experts, as shown in Table 2.2. The collaboration is grounded in a new type of professional development structure, where learning occurs with an experienced colleague affiliated with an expert external support system (i.e., the science coach’s association with an informal science-rich institution).

Summary

In the following chapter, the methodology and methods are presented. The study follows a qualitative research design based on the theoretical frameworks discussed. The research design and methods are also outlined to explain how the CDLN model is tested using a reciprocal PD philosophy, with the science coach playing a pivotal role in the diagonal relationship.

Table 2.2. *Characteristics of Learning Networks*

	Vertical *Mechanical*	Diagonal *Reciprocal*	Horizontal *Organic*
Actors	Officials, Specialists	Instructional specialists, lead teachers, and museum educators	Groups
Processes	Linear, Planned	Mutualistic, planned and integrated into curriculum/teaching	Organic, integrated
Structure/ Content	Job-oriented structure/learning programs	Classroom and museum-based learning programs	Problem-oriented open learning programs
Organizational Structure	Formalized relations; Students	Cooperative relations; teachers, specialists, and informal institutions	Horizontal relations, group members

Adapted from Van der Krogt, 1998, p. 165

Chapter III

DATA SOURCES AND METHODOLOGY

Field Settings and Participants

This research study took place at a public elementary school (hereafter "Star Elementary") and at a large natural history museum (hereafter "Museum"). The school site, Star Elementary, is a medium-sized public elementary school in a large urban city with 483 students from pre-kindergarten through grade 5. The school population is comprised of 45% Hispanic, 25% Black, 21% White, and 4% Asian students. The student body includes 12% English language learners (ELL) and 12% special education students. Boys account for 51% of the students enrolled and girls account for 49%. The average attendance rate for school year 2009-2010 was 93.5% (New York City Department of Education, 2010).

The passing rate for the Grade 4 State Science Exam has decreased, as compared to the rest of the city since 2008, with Star Elementary showing a proficiency rate of approximately 19% less than the city. The marked decrease might be partly due to the unfortunate passing of the science cluster teacher in the school that same year (science cluster refers to a teacher who only teaches the subject of science to multiple grade level classes). Prior to 2008, 4th graders at Star Elementary were only 4.8% behind the city passing rate in science. The school utilizes the city-sponsored core curriculum science kit program called the Full Option Science System (FOSS) and a text-based program called Harcourt.

The Museum served as the second site representing the informal institution. The first informal PD session was conducted by Violet, and the last two were facilitated by Lillian (pseudonyms are used for both Museum educators), both of whom are veteran staff in the Education Department of the Museum. The teacher professional development programs at the Museum typically immerse school teachers into science and social studies content through lectures, guided explorations of the exhibits/halls, and hands-on inquiry-based classroom activities.

Four teacher participants were selected by the administration as representatives of different grade levels because they showed a willingness to engage in school initiatives. The four teachers were a 4th grade ELL teacher, Leah (pseudonyms of teacher participants were chosen by the teachers themselves); a 3rd/4th grade Special Education teacher, Ada; a 2nd grade general education teacher, Maria; and a 3rd grade general education teacher, Venus (who has also served as the science liaison in the school since the passing of their science cluster teacher in 2008). The science curriculum at Star Elementary follows the City Science Scope and Sequence (New York City Department of Education, 2008). During the period of this study, the 3rd grade class was working with the Full Option Science System (FOSS) Measurement kit.

For this study, I served as science coach (hereafter "science coach" or "coach") as well as a participant-researcher at Star Elementary, conducting demonstration lessons, observing teachers conduct science lessons, facilitating in-house workshops, and coordinating workshops at outside venues. Although the goal of the researcher was not to directly emerge and enculturate myself with the participants, as an ethnographer would, I did focus my lesson observation, PD session participation, and research on one aspect of the elementary teachers, namely their experience in the CDLN PD cycle (Charmaz, 2006). As a participant observer, according to Guba and Lincoln (1981), the researcher assumes "*two* roles...an observer...[and] also a genuine participant...and has a stake in the group's activity and the outcomes of that activity" (pp. 189-190). On one hand, I was an active participant conducting the formal PD in the cycle and giving advice to teachers' before and after their lesson observations; on the other hand, I served as an observer taking field notes during the lesson and engaging in the informal PD sessions at the Museum. I was able to play a dual yet critical role as a science coach in the CDLN cycle, offering guidance in some cases and supporting their learning at the Museum in other cases. Merriam (1998) stresses "how the researcher can identify those effects [of being a participant observer] and account for them in interpreting the data" (p. 103). In this study, my role as a participant observer enabled me to maintain a close unique relationship and understanding of the teacher experiences, which in effect helped to guide data collection and analysis.

Research Design and Methodology

This study adopted a qualitative approach to data collection and analysis using interviews, observations of teachers conducting a science lesson, and pre/post observation surveys. In addition, one elected case study is highlighted using an in-depth micro grounded theory analysis (Strauss & Corbin, 1998).

The rationale for this qualitative study builds on a substantive theory regarding new forms of professional development and a teacher's pedagogical content knowledge (PCK). PCK stems from a socio-constructivist epistemological framework in which knowledge acquisition is an active context-based driven process. A constructivist grounded theory methodology was used as the research paradigm to test classroom-based PD (Charmaz, 2006).

This study was conducted with four elementary teachers, Grades 2 (1), 3 (1), and 4 (2), two museum educators, and one science coach using a professional development cycle in both formal and informal settings. The participants were involved in the following PD activities:

- Formal content and lesson-focused PD at school meetings
- Informal PD sessions at museum
- Pre- and post-observation conferences at school
- Demos/Lesson observations conducted by science coach

As shown below in the Research Action Plan (Table 3.1), this study was conducted during a period of four months and explored the role of the science coach as a mentor with ties to an informal educational institution. The study looked closely at how a science coach can help teachers learn content, materials/classroom management, pedagogical skills, and the use of formal and informal institutions during the implementation of a city-sponsored science curriculum that utilizes kit and text-based materials.

In Chapters IV, V, and VI, detailed descriptions of the research design are presented along with additional unanticipated outgrowths of the action plan with respect to data collection sources.

Data Collection

Table 3.1 shows how and where the PD was conducted as well as the data sources used. The primary sources of data were: (a) teacher feedback from lesson demonstration/ observations; (b) Museum PD sessions and coach-led PD sessions; (c) open-ended questionnaires before and after Museum/coach-led PD; (d) semi-structured teacher interviews; and (e) artifact collection. The secondary sources of data were: (f) field notes from observations as an observer more than a participant (during classroom teacher-led lessons); (g) field notes from observations as a participant (during science coach-led demo lessons); and (h) field notes from observations as a participant in Museum/coach-led PD sessions.

All PD sessions and interviews were audiotaped and transcribed. The observation field notes of the teacher's lessons were written in the researcher's field journal. Observations and audio recordings were combined to form layered descriptions of the effectiveness of the CDLN science coach/Museum mentoring model (Merriam, 1998). While the resultant descriptions focused on teachers' acquisition of science content knowledge, science pedagogical knowledge, science pedagogical content knowledge, and

Table 3.1. *Research Action Plan*

Research Site	Delivery Mode of PD Program/Data Collection*
1) Star Elementary - Month 1	• Intro meeting • Informal discussions with all teacher participants • In-house content and lesson-focused PD • Lesson planning/pacing • [FPD] [Q] [OC] [FN]
2) Star Elementary - Month 2	• Informal discussions with all teacher participants • In-house content and lesson-focused PD • Lesson planning/pacing • [FPD] [Q] [OC] [FN]
2) Museum - Month 2	• Informal discussions with all teacher participants • Content and lesson-focused PD • Object observations/science notebooking museum resources • [IPD] [Q] [FN]
3) Star Elementary - Months 2-4 Teacher's Classroom during Preparation and/or Regular Science Period	• Pre-conference • Demo lesson by science coach • Lesson observation viewed by science coach • Post-conference • [FPD] [OC] [FN]
5) Museum - Month 3	• Informal discussions with all teacher participants • Content and lesson-focused PD • Diorama/exhibit observations • [IPD] [FN]
6) Museum - Month 4	• Informal discussions with all teacher participants • Content and lesson-focused PD • Diorama/exhibit student problem & hypothesis development • [IPD] [Q] [FN]
7) Star Elementary - Month 4	• Exit meeting • Informal discussions with all teacher participants • In-house content and lesson-focused PD • Scientific method/science notebooking • [FPD] [Q] [FN]

*Informal PD Sessions at Museum/Group Interviews [IPD]
Pre- and Post-Observation Conferences at School [OC]
Formal PD Sessions at School/Group Interviews [FPD]
Formal/Informal PD Questionnaire [Q]
Science Coach/Researcher Field Notes [FN]

Museum resource usage, the research methods cut across constructs and were used to build a holistic description of the teacher's pattern of learning. In this way, there is not a one-to-one mapping of data sources; rather, each source contributed one or more pieces to the overall description of the coach's and museum educators' influences on the teacher participants. An overview of the primary data sources are described in the following sections.

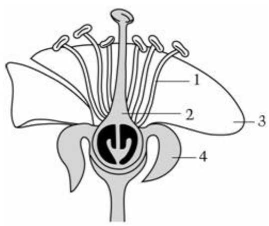
Participant Lesson Demonstration and Observations

Through the cognitive apprenticeship model, the teacher participants observed a demo science lesson developed and conducted by the science coach. As Collins, Brown and Holum (1991) explained, the most successful way for novices to learn is where they work alongside experienced masters. Thus, it is important for a teacher to have a coach who is a master of the subject area to explain the PCK necessary to reach a mastery level.

The teachers were asked during their individual interviews what they needed help with in their teaching and what they would like to see being taught to their class. Ada (grade 3/4 special education teacher) received a demo lesson based on her concerns for the performance tasks on the Grade 4 State Science Exam which is not covered in the core curriculum approved by the city. I conducted a double-period lesson (1.5 hours) on determining the volume of an irregular-shaped object using water displacement. Leah (grade 4 bilingual teacher) also had concerns about the state science exam and I did a double-period lesson on determining the distance traveled by a toy car released from a ramp at varying heights. Maria (grade 2 teacher) and Venus (grade 3 teacher) wanted ideas on how to supplement their core curriculum lessons based on the current unit and to prepare their students for the Grade 4 State Science Exam questions. I conducted a single-period lesson (45 minutes) on identifying the parts of a flower through a tiger lily dissection. I decided to conduct this lesson because it was one I always did with my classes when I taught as a science cluster teacher. It is a lesson with added rigor based on a question one might see on the National Assessment of Educational Progress (NAEP) exam rather than a less difficult question seen on the Grade 4 State Science Exam (Figure 3.1).

Based on field notes, an ethnographic method of direct observation protocol (Appendix A) was used. I generated a physical sketch of the teacher's classroom, and descriptive notes and reflections on the chronological series of activities occurring in the science lesson between the teacher and the students (Creswell, 2007). It is important to note that these field notes concentrated on the teacher's execution of the science lesson—how content was presented, how materials were managed, and what means were used to assess students' knowledge. After the lesson was completed, as part of the on-site professional development, I conferenced with the teacher during her lunch or preparation period by providing tips and feedback about the lesson recently viewed. A semi-structured open-ended interview protocol was used in which I asked the teachers: "How did you think the lesson went?"; "What were some things that went well?"; "What were some things that you could do better next time?"; and "What would you like me to help you with?"

Sample question from Grade 4 NAEP Science Exam (2005, Grade 4, Block S12, Multiple Choice question, Difficulty: Hard, "Parts of A Flower")



Which two numbers in the picture above of a flower show the male and female parts? Answer: A

A 1 and 2

B 2 and 3

C 2 and 4

D 3 and 4

Sample question from Grade 4 New York State Science Exam, 2008 (Question #18, MST Learning Standard 4, Living Environment, Key Idea/Major Understanding 3.1b)

Each plant has different structures that serve different functions in growth, survival, and reproduction.

- roots help support the plant and take in water and nutrients
- leaves help plants utilize sunlight to make food for the plant
- stems, stalks, trunks, and other similar structures provide support for the plant
- some plants have flowers
- flowers are reproductive structures of plants that produce fruit which contains seeds
- seeds contain stored food that aids in germination and the growth of young plants

Which part of a plant takes in water and nutrients from the soil? Answer: A

A root

B stem

C flower

D leaf

Figure 3.1. Sample Science Summative Assessment Questions

<u>Professional Development Workshop Sessions</u>

The formal PD was a set of three 45-minute audiotaped sessions conducted at the school by the science coach. The first introductory session was attended by all four teacher participants and the assistant principal in the assistant principal's office. The next two sessions only included the four teacher participants—the second held in the assistant principal's office and the last in the school's library. At the end of the first and last sessions, two museum tickets were given to each member present. The content of the sessions included: administration of the formal pre/post questionnaires; discussions about what lessons they were doing around the current science unit of study; available Department of Education curriculum resources; a timeline of the scope and sequence; and when they planned to teach science in their weekly plans so I could come and observe.

The informal PD was a set of three 1.5-hour audiotaped sessions conducted at the Museum by two museum educators. These sessions were set up like a workshop. The workshop session consisted of a mini-lesson, where the inquiry skill (i.e., observation, question development) was taught to the teachers followed by implementation of the skill using a group activity (i.e., museum object observation, diorama study). An additional 30 minutes was set aside to debrief with the science coach, which served as another component of the formal PD conducted by the school mentor, albeit outside the school walls. All Museum sessions were attended by all four teacher participants, the Museum educator (Violet during the first session and Lillian during the last two sessions), and the science coach. My role during the first 1.5 hours was that of a participant-observer, where I assumed the role of a workshop participant. I took field notes similar to the protocol followed during lesson observations, where I chronicled descriptive notes in the first column and made reflections in the second column.

The participants first met in a small room inside the Museum, where the Museum educator gave them a half-hour workshop on the process skill or teaching strategy they were focusing on for the day. Resources were given out (i.e., handouts, articles, books, educator guides) and the participants were taken out to the exhibits, dioramas, and/or Halls where the skill/strategy was employed. All participants then returned to the small room to end the day with a summary of how each person used the skill/strategy as a student in the workshop and how they could use it with their classes. A detailed account of the three informal PD sessions is presented below.

• Informal PD Session #1: Violet talked with the teachers to find out how often they used the Museum or other informal institutions in the city as a public visitor or as a teacher. She informed them of upcoming events and education resources available to them. Violet then introduced the teachers to the inquiry process skill of observing. She brought in a cart filled with various objects (e.g., shells, stuffed birds) and allowed the participants to choose one to examine closely using an "Object Observation Sheet," calipers, and a hand lens which she gave out. Violet also gave each participant the book *Using Science Notebooks in Elementary Classrooms* (Klentschy, 2008); one article, "Pigeon—Friend or Foe? Children's Understanding of an Everyday Animal" (Tunnicliffe, Boulter, & Reiss, 2007); and one chapter excerpt entitled "Objects of Learning, Objects of Talk: Changing Minds in Museums" (Leinhardt & Crowley, 2001) as resources to take home. She briefly talked about where observation, description, and questioning might fit into science notebooking. Afterwards, the participants viewed the temporary exhibit “The Silk Road” and were shown how to use an exhibit with the accompanying Educator Guide.

• Informal PD Session #2: Lillian continued with building teachers’ observation skills by viewing dioramas and exhibits (e.g., Snails and Marine Animals, Life of John Burroughs, pictures of nature scenes) in the Hall of Ocean Life (e.g., Northern Sea Lions, the Squid and the Sperm Whale) and the Hall of Biodiversity (e.g., Tree of Life, Extinct/Endangered Animals). She allowed the participants to observe, describe, and begin questioning what they saw in each diorama/exhibit space. After a period of meaningful observation, she gave the teachers some background content knowledge and the exhibit space context. As a resource, she handed out a web article she authored entitled “Observing Dioramas” (Breslof, 2001) and an essay by Barrett Klein entitled “Drawing as a Way of Looking at the Natural World.”does Breslof give away identity?

• Informal PD Session #3: Lillian started the session with a discussion around the two resources she handed out last time. She also gave the teachers a third Museum trip educator’s resource*, Diorama Inquiry Skills,* which was a guide to help students develop their problem-solving skills based on scenes in the diorama. Lillian prompted them to come up with a problem, a prediction, and evidence from the diorama scene. For example, students are able to decipher a window that leads into a world of animals, their habitat, their behavior, and a captured moment in time. By observing the deer in a forest diorama, the teachers used their observation skills to develop a problem and a relevant prediction by citing evidence from the diorama through careful study and analysis.

• Informal PD Sessions #1-3: After the 1.5-hour session with the Museum educator, an additional half-hour was set aside to debrief with the science coach. During these last 30 minutes, the following activities were completed: administration of the informal post questionnaire; discussion around their favorite part of the Museum they visited that day and how they would use the Museum resources with their students (e.g., Educator Guides, "Moveable Museum"); discussions about what lessons they were doing around the current science unit of study; available online Educator Guides for current and temporary exhibits; information on upcoming events (i.e., Education Department Program flyers, Spring Museum calendar); distribution of supplemental resources (i.e., NSTA membership information, NSTA magazine article "Defining Inquiry" by Martin-Hansen, 2002); timeline of the NYC science scope and sequence; and their weekly plans to teach science so that I as the science coach could come to observe their lesson plans.

<u>Pre/Post Questionnaires</u>

An open-ended questionnaire (Appendix B) was given to the four elementary teachers during the first and last sessions of the formal and informal professional development. The formal pre-PD questionnaires asked the participants to if and what kind of PD they received from a science coach up until that point. The formal post-PD questionnaires asked the participants to assess the quality of the school-based PD they received from the science coach. The informal pre-PD questionnaire asked the participants if and what kind of PD they have attended given by an informal institution (such as aquarium, museum, science center or park). The informal post-PD questionnaire asked the participants to assess the quality of the Museum-based PD they received from the Museum educators. The open-ended questions prompted feedback that addressed the research questions. The responses were intended to assess the degree of content learned or clarified, teacher practice learned, and when the teacher visited or plans to visit the Museum.

Individual/Group Teacher Interviews

Semi-structured individual interviews were conducted during the pre/post observation conferences (see the Interview Protocol in Appendix C). The interview protocol was developed specifically for this study, with the majority of questions aligned with the formal PD and the assistance they received or wish to receive from the science coach as it relates to the science curriculum, core curriculum materials or instruction.

Group interviews were conducted during the PD sessions and were digitally recorded. The group interviews were conducted using an unstructured approach that had "open-ended questions, [was] flexible/exploratory, [and] more like a conversation" (Merriam, 1998, p. 73). New insights, information, and understanding can be obtained in informal group interviews. Questions were designed to have teachers share their uses of the materials distributed in the PD sessions, their museum access, and their attitudes toward PD, science, and science teaching.

Artifact Collection

Over the course of the study, I collected photographs of various classroom and field observations. During the pre/post lesson observation conferences, I viewed the learning environment of the classroom and photographed the science bulletin boards, reference charts, student work posted, as well as teacher-made reference charts/templates associated with the lesson of the day displayed on the blackboard. In addition, I photographed some of the dioramas that were viewed during the informal PDs, students on field trips, and class museum trip documents that were used by the teacher. A photo archive was used to gain a pictorial representation of the teachers' natural world as a means of visually-recorded field notes and to triangulate analysis with the other data source methods. These documents provided contextual descriptions as well as teacher-generated worksheets and points of discussion with the teachers.

Data Analysis

Data were analyzed using a case study method, in which a holistic and intricate view was prepared to examine the teachers' mindset, interest and knowledge of science, the role of the science coach, and the implementation of the school's science curriculum. A detailed description of data analysis is given in each set of findings in Chapters IV, V, and VI.

Reliability and Validity

In terms of reliability, I disclosed my role in the study as an informal workshop participant; as an observer of lessons, workshops, and field trips; and as the researcher of the study. A full description of my role was necessary to clearly identify my status within the group of participants. Thus, findings should be understood from my viewpoint solely as a researcher, with certain entry points into the study as an active participant.

First, data were collected in multiple forms and from different parts of the PD cycle in order to triangulate results and provide evidence across learning settings, thereby accounting for variations between different data collection methods (e.g., workshop session conversations versus questionnaires versus direct observation of individual behaviors during a lesson). Second, whenever possible, data were presented verbatim and interpretations were made explicit to provide transparency in the presentation of results. This was done to allow peers, researchers, and reviewers to assess the worth of the results presented in each study.

In terms of validity and evaluation, this research met the criteria outlined in Creswell (2007) as accurately reflecting a high-quality grounded theory study. The formal and informal interactions within the CDLN model were investigated as the key elements in the theory interaction being studied. The data were coded using open, axial, and selective coding categories to present the theoretical model in a modified diagram and storyline. In addition, as mentioned above, self-disclosure by me as the researcher about my stance in the study was reflexive. When reviewing the data instruments used, content validity was also high because I, as the science coach and researcher in this study, was able to design these instruments in accordance with my own experiences as a science teacher and my knowledge of elementary school workshop model lessons. The content development of the original data sources, such as formal workshop session agendas, a teacher lesson observation protocol, and a semi-structured interview protocol, were generated in situ as a result of previous experiences.

Limitations

I note three limitations that I encountered during the study: trust, time, and generalizability. First, I had to quickly establish a sense of trust with the two administrators, the principal and the assistant principal, as well as the four teachers directly involved in the study. I had to familiarize the teachers with the action research process, my dissertation topic, and the overall significance of the study I envisioned for teacher professional development. After their trust was gained, the second limitation was time. The administrators were initially delayed in setting up the study in general and then in devising a schedule each time a workshop session needed to be conducted, either on site or off site in the Museum. The allotted time could not infringe upon existing school events or the teachers' personal time commitments after school (the sessions often ran over the typical work day by half an hour and their preparation period was substituted with group in-house PD or interviews). Lastly, generalizing findings are often considered a limitation to case study research in general. For example, looking at a limited scope of the elementary teacher population, it is uncertain whether the data and results can be representative of all elementary school teachers. However, the findings from this study do indicate significant implications for elementary science education and for literature in professional development overall. In the following chapters, the findings of the study are presented in the format of three publishable papers.

Chapter IV

DIAGONAL SCIENCE COACHING: THE DEVELOPMENT OF PEDAGOGICAL CONTENT KNOWLEDGE IN ELEMENTARY TEACHERS

Abstract

This study examined how the science coach and museum-based professional development (PD) shaped the acquisition of teachers' pedagogical content knowledge through a Collaborative Diagonal Learning Network (CDLN) model. This is a qualitative research study based on a constructivist grounded theory methodology. The participants were four elementary school teachers who were teaching science in their respective classrooms approximately once a week. Major data sources were PD sessions, classroom observations, and interviews. Data analysis indicated that these teachers developed content-specific teaching strategies. Based on the CDLN model of organizing and providing support to meet individual and group needs, the elementary teachers developed new skills and behaviors, including: (a) strategies to use science notebooks, (b) professional learning communities, (c) self-efficacy, (d) instructional differentiation, e.g., revised museum trip worksheets, and (e) strategies for a unit-based class museum trip. Based on the emergent teaching skills and behaviors, three main categories arose from data analysis: development of pedagogical content knowledge (PCK), knowledge of museum education, and increased self-efficacy.

Keywords: Science Coach • Museum Learning • Pedagogical Content Knowledge • Elementary Teachers • Self-Efficacy • Professional Development

Introduction

Elementary teachers rarely visit museums with their classes to deepen their students' content or to enhance their own pedagogy. Tal and Steiner (2006) found that 53% of the elementary teachers surveyed went to a museum because it was an opportunity for having personal experiences; 47% mentioned doing experiments that cannot be done in school and completing or adding to the curriculum currently being taught. Only secondary teachers indicated enrichment in science, exposure to a “scientific environment,” and higher-level teaching as visit reasons. Even for the sake of organizing a visit, communication only occurred between elementary school personnel and museum reservation and content coordinators. There was little or no communication between the actual elementary teachers taking their classes and the museum.

Administrators, such as the principal, assistant principal or museum trip coordinator, were the primary points of contact and planners in 83% of the cases. However, 50% of secondary teachers (0% for elementary teachers) communicated at a *pedagogical-content* level, in which a mutual planning of the visit was done between the teacher and a museum domain coordinator, who guided the teacher in selecting a topic, lab activities, and the concepts to be taught. Because no museum visits were coordinated at a pedagogical content level by elementary teachers, this fact emphasizes the deficit that elementary science education faces today. There is a lack of communication and motivation when planning and visiting an informal science institution for the purpose of deepening elementary students’ subject-specific content knowledge and the way in which it is taught. This study sought to bridge the gap in communication and pedagogical content knowledge for elementary school teachers.

Review of Literature

Pedagogical Content Knowledge (PCK)

While some scholars stress the importance of knowing one's subject matter in teaching science, there is significant evidence that content knowledge alone is insufficient to support student learning. Shulman (1986) asserts that "mere content knowledge is likely to be as useless pedagogically as content-free skill" (p. 8). Therefore, there is a need within science education reform for teachers to develop knowledge in addition to mere subject matter knowledge: a knowledge base that bridges conventional areas of subject matter and pedagogy to produce a compound knowledge base for teaching. In this vein, Shulman (1986) coined the concept of pedagogical content knowledge, or PCK, as a "distinctive body of knowledge for teaching in order to acknowledge the importance of the transformation of subject matter knowledge per se into subject matter knowledge for teaching" (Park & Oliver, 2009, p. 336).

PCK "represents the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organized, represented, and adapted to the diverse interests and abilities of learners, and presented for instruction" (Shulman, 1986, p. 8). Although subject matter knowledge is a prerequisite for PCK (van Driel, Verloop, & De Vos, 1998), taken together, the skill to teach science adequately is one of the responsibilities listed in the job description of an elementary school teacher. In keeping with Shulman's definition of PCK, I interpreted the literature as indicating that teachers' development of PCK relative to science is particularly dependent upon knowing their science learners within the classroom setting—in terms of learning difficulties, English language acquisition, misconceptions, abilities, and interests. In this regard, elementary science teachers of all grades and student learning needs (i.e., special education and English Language Learners) need to be on familiar terms with student characteristics both as individuals and in groups (Park & Oliver, 2009; van Driel, Verloop, & De Vos, 1998).

Elementary Teachers and Science PCK

Elementary teachers are only required to know a general overview of scientific facts, but they must also be able to know how to *teach* the science in the curriculum and to follow the mandated scope and sequence. Elementary teachers as well need to know how to generally organize the big ideas in science and the nature of science in terms of inquiry. If a teacher does not understand how their students might approach a topic or any misconceptions they bring to class or may form while they are there, the teacher will be ineffective in the construction of students' knowledge. In addition, the teacher should be able to explain and present the topic under study in various ways if one way does not work. The teacher, just like a performer, should be able to reach into a "bag of tricks" to try another method (Shulman, 1986, pp. 202-203). Yet novice teachers might not be able to adapt their teaching practices because they lack the professional maturity to attain a thorough development of PCK. However, one way to solve this problem for elementary school teachers, as previously stated, is to provide in-service (or pre-service) training in hands-on experimentation including predicting, discussing, and reflecting (Summers, Kruger, & Mant, 1998).

Through professional development, teachers can deepen and extend their content knowledge. For elementary teachers who teach a broad range of subject areas, this is especially important in order to connect the discipline to their students (Feiman-Nemser, 2001). Spillane, Diamond, Walker, Halverson, and Jita (2001) recognize that science teaching in elementary school is a problem because of increased emphasis on reading and math, limited time to teach science, and the teacher's lack of training. The degree of teachers' PCK and content knowledge contributes to the difficulty of teaching in elementary school. When planning PD, these and other factors such as classroom management and a teacher's expertise should be taken into account. Thus, PD should be differentiated depending on a teacher's proficiency level in the subject, and one content area should be studied at a time. In this way, teaching practices are embedded along with the studied content (Smith & Neale, 1989).

<u>Standards-Based Elementary PD That Supports Collaboration</u>

A collaborative learning environment is an essential component of effective professional development. In the National Science Education Standards (NSES or Standards) (National Research Council [NRC], 1996), Standard 4 addresses the professional development of teachers of science. The NSES presents four PD standards, and collaboration is a requirement for each to be fulfilled to its maximum potential. Professional development Standard A states that in PD, teachers of science, especially elementary teachers, should learn science content through an inquiry lens. PD should also encourage and support science teachers in efforts towards collaboration for science learning practices. For example, "elementary teachers of science need to have an opportunity to develop a broad knowledge of science content in addition to some in-depth experiences in at least one science subject" (p. 60). With an in-depth knowledge, teachers of science are prepared to guide student inquiry activities, identify student misconceptions, and devise a way to foster student understanding. "Although thorough science knowledge in many areas would enhance the work of an elementary teacher, it is more realistic to expect a generalist's knowledge" (p. 60). Teachers in elementary schools usually do not concentrate on one particular discipline while in a teacher preparation program to obtain full licensure. Therefore, reform in the content and teaching of undergraduate science courses and within teacher education courses, such as science methods, is crucial to the implementation of the NSES. The NSES recommends that science and science education faculty not only team-teach, plan group investigations, use technology, and read scientific literature, but also allow their students to learn scientific concepts through inquiry (NRC, 1996).

Professional development Standard B states that PD for teachers of science should connect their content knowledge with their pedagogical (curriculum and teaching) knowledge. With continuous practical experiences and time for analysis, teachers can tailor science instruction to meet the diverse needs of their students, a key indicator that one has achieved a minimum level of PCK. The development of PCK in science by teachers is similar to student learning in science. Teachers must engage in scientific inquiry through practice and collaborate with teachers and other colleagues to self-reflect by posing questions to oneself (NRC, 1996).

Professional development Standard C states that PD for teachers of science should include regular and continuous chances for lifelong learning. PD activities must allow for self-assessment and collegial feedback. Teacher support can be achieved by preparing and using mentors, master teachers, and coaches. Since teachers leave pre-service programs at colleges and universities without a full and complete understanding of science content and pedagogy, teachers should look for, be offered, and be allowed in-service time to continue to deepen their science content as part of their professional responsibility (NRC, 1996)—hence, the need for informal science institutions to be involved with offering PD. Museum education is a field of study born out of the need for museums to be a teaching entity for the public using real objects. As Hein (2006) notes, "Museum education converges with social responsibility: the social service that museums, as public institutions, provide is education. A constructivist or progressive educational mission necessarily puts an emphasis on social change" (p. 10). In this case, social change for the betterment of the larger society relates to teachers educating children. Through PD, museum educators seek to provide pedagogues with the knowledge for "repeated and continuing inquiry, such as open-ended questions, lots of materials, or alternative possible approaches to inquiry" in the classroom (p. 11).

Professional development Standard D emphasizes the need for quality pre-service and in-service programs characterized by: a shared vision of science learning, coordination of program components, options that delineate the diverse needs of teacher proficiency, collaboration with program members, acknowledgment of school culture, and program assessment. "The strongest programs result from collaborations among teachers, developers (such as science coordinators), and other stakeholders (such as scientists, science-rich centers, and community organizations)" (NRC, 1996, p. 71). Such collaborations bring a rich variety of expertise and resources that share a common vision to help teachers achieve standards of excellence (NRC, 1996).

The National Science Teachers Association (NSTA) has created its own set of standards specifically geared towards colleges and universities, known as the NSTA Science Teacher Preparation Standards. The document suggests the preparation of elementary science teachers to utilize effective teaching strategies to ensure their conceptual understanding of science. The need for effective science instruction often causes apprehension and anxiety for teachers. For example, the added stress of mandatory testing in science by the No Child Left Behind (NCLB) legislation which started in 2007 may lead science teachers to believe they are inadequately prepared in both content knowledge and scientific inquiry experiences. But the NCLB guidelines also stipulate support for effective teaching of science, especially to achieve certification (Johnson, 2007). Thus, NSTA (2003) has outlined unifying science content recommendations and practices for various levels of the elementary teacher:

- Elementary generalists *without* specialization:
  - a strong emphasis on observation and description; manipulation of objects
  - identification of patterns in nature across subjects; systems
  - engage students in concrete manipulative activities through investigation
- Elementary general science teachers *with* a specialization:
  - strong emphasis on collaborative inquiry in the laboratory and field
  - a deeper content understanding than generalists, but across theme and disciplines

- same as generalists but be prepared in their subject specific area

At the elementary level, especially for generalists (i.e., teachers without a science content background or major in a field of science), teacher preparation programs should require inquiry-based science courses. In a research review, the NSTA (2003) found that the use of constructivist teaching methodologies improved the learning of science by elementary education candidates. With the inclusion of inquiry-centered courses and teacher induction programs, the self-efficacy of elementary teachers may increase due to their aptitude in science (Stansbury & Zimmerman, 2002).

Collaborative Diagonal Learning Network (CDLN)

The Collaborative Diagonal Learning Network (CDLN) is a researcher-coined term used in this study that identifies the link that can be established between formal (school/classroom) and informal (museum) experts in the field in order to develop the pedagogical content knowledge of teachers of science (Figure 4.1). Professional development is usually received from a top-down approach (i.e., vertical learning, Van der Krogt, 1998) from school administration, district supervisor or coach. Teachers can also be given professional advice across the grade from fellow colleagues (i.e., horizontal learning, Van der Krogt). However, to enhance collaboration among all parties within the science education community, a new dimension was added to the typical formalized PD format—an informal public science institution. Hence, the CDLN was developed as a theoretical model with three distinct formal and informal interactions, which are examined in this current study: the science coach, a natural history museum, and the teacher.

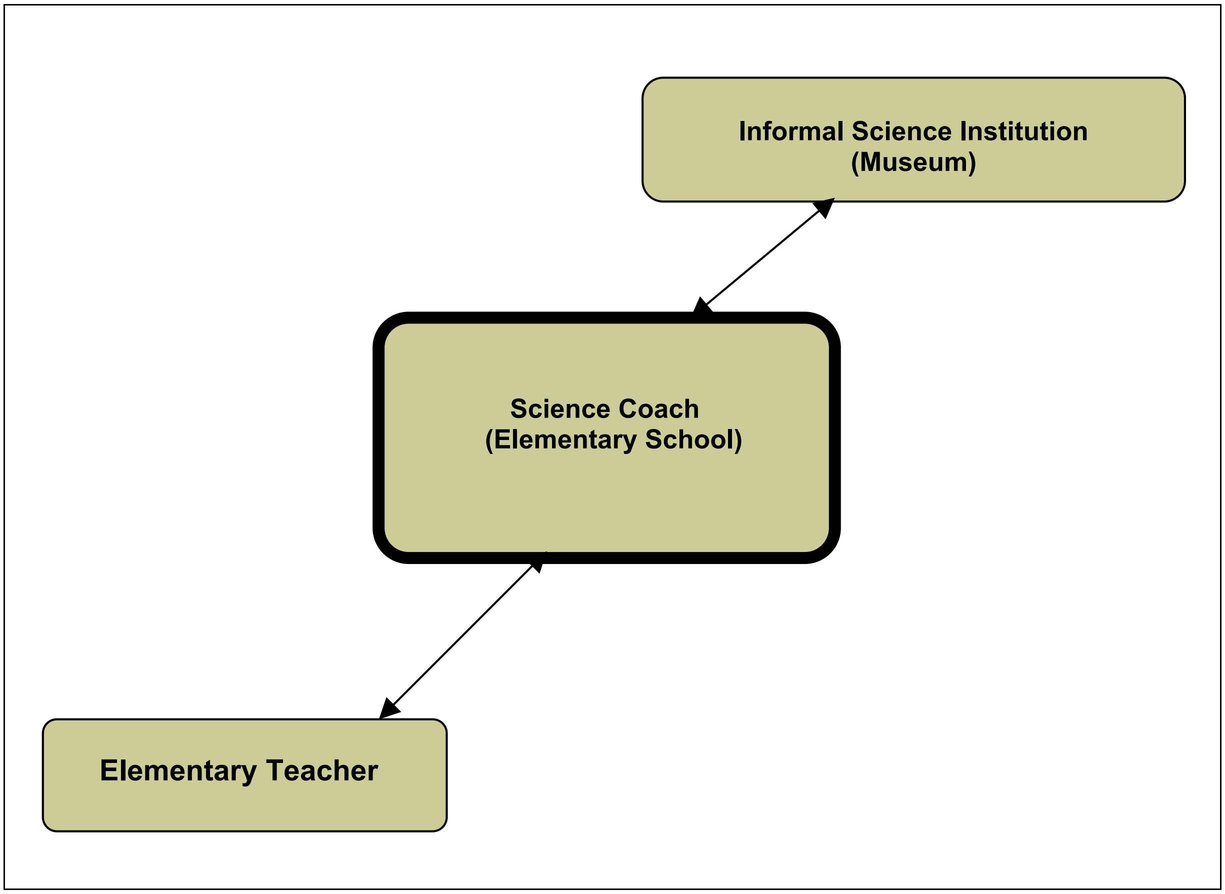


Figure 4.1. Collaborative Diagonal Learning Network (CDLN) —Theoretical Model for Interrelationship with Formal and Informal PD Providers

The goal of the CDLN is to serve as a program model for professional development in elementary science reform. The CDLN includes a direct and sustained relationship between the school's science coach through in-house workshops, demonstration lessons, teacher observations as well as mini-institutes at an informal institution. Thus, the goal for this study was to understand, through this diagonal relationship, how novice elementary teachers increase their pedagogical content knowledge (PCK), as Shulman (1986) identified through instruction in hands-on science professional development with the aid of a science coach, and museum-led workshops.

The primary research questions for this study were: How does the Collaborative Diagonal Learning Network (CDLN) model enhance elementary teachers' acquisition of pedagogical content knowledge (PCK)? More specifically, how does the *science coach* enhance elementary teachers' acquisition of PCK, how do *museum-based workshops* enhance elementary teachers' acquisition of PCK, and how do the *science coach and museum-based workshops* enhance elementary teachers' acquisition of PCK?

Methodology

Research Design

Using the framework of PCK, this qualitative study sought to build on a substantive theory regarding new forms of professional development and a teacher's PCK. PCK stems from a socio-constructivist epistemological framework in which knowledge acquisition is an active context-based driven process. A constructivist grounded theory methodology (Charmaz, 2006; Strauss & Corbin, 1998) was used as the research paradigm to study formal-based (classroom) and informal-based (museum) PD. The study was conducted with four elementary teachers, two museum educators, and one science coach using a professional development cycle in both formal and informal settings.

Setting

This study took place in two settings: Star Elementary (pseudonym), a mid-sized (K-5) urban school, and a large natural history museum, the Museum (pseudonym). The study occurred over a period of four months, with three formal PD sessions occurring at Star Elementary and three informal PD sessions occurring at the Museum.

According to a Quality Review Report (New York City Department of Education, 2010), Star Elementary is described as a developing school with a student enrollment of 483 students from pre-Kindergarten through grade 5. The school population is comprised of 25% Black, 45% Hispanic, 21% White, and 4% Asian students. The student body includes 12% English language learners and 12% special education students. Boys account for 51% of the students enrolled and girls account for 49%. The average attendance rate for the 2009-2010 school year was 93.5%.

The student body at Star Elementary is widely diverse, including children of famous actors to children of parents who live in city housing all within the same classroom. The very involved Parent Teacher Association (PTA) takes pride in its ability to partner with outside non-profit organizations. The PTA often funds, organizes, and schedules programs and field trips with the assistance of the principal for all grade levels, sometimes without the input of the teachers. Despite the absence of the beloved science teacher who passed away a few years prior to this study, the school places great joy and hope in their new science lab. Although building the science lab seems to be a top priority of the principal, furnishing it is a second priority, and building teachers' knowledge to utilize the science lab is totally neglected, placing it as a distant third on the list. Yet the principal was willing and eager for me to come in and support her teachers in science, realizing their deficit, but also recognizing the school's promise once the construction of the lab was completed at the end of the year.

The Museum is one of the largest natural history museums in the world and is located a mere 12 blocks away from the school; however, the distance in terms of utilization is very far. The Museum houses an Education Department devoted to the learning of all ages, paying particular attention to an underrepresented group of learners—public school teachers. The Education Department uses the temporary and permanent exhibits in the Halls to address the lack of content knowledge and/or teaching applications that teachers face.

Participants

As the participant-researcher for this study, I was also the "coach" or "science coach." One Museum educator, Violet, conducted the first informal PD session, and another Museum educator, Lillian, facilitated the last two sessions (pseudonyms are used for both Museum educators). Both are veteran staff in the Education Department of the Museum.

Four participants were purposefully selected by the principal of Star Elementary. The selection of teachers allowed for a diverse group representative of the school's student population. Hence, the four teachers encompassed a broad range of grade levels and student learning needs. The teacher participants (pseudonyms of teacher participants were chosen by the teachers themselves) were a 4th grade ESL teacher, Leah; a 3rd/4th grade Special Education teacher, Ada; a 2nd grade general education teacher, Maria; and a

3rd grade general education teacher, Venus (who also served as the science liaison in the school since the passing of their science cluster teacher a few years ago). The science curriculum at Star Elementary uses the city-sponsored science core curriculum text/kit programs called Full Option Science System (FOSS) and Harcourt. The science kits follow the city's scope and sequence and pacing calendars.

Data Collection and Analysis

The four participants were involved in the following formal (school/classroom) and informal (museum) PD activities:

- Formal content and lesson-focused PD at school meetings
- Informal PD sessions at Museum
- Pre- and post-observation conferences at school
- Demos/lesson observations conducted by science coach

During the aforementioned activities, the primary and secondary sources of data collected were: (a) audiotaped PD sessions; (b) open-ended pre/post questionnaires; (c) audiotaped semi-structured group teacher interviews; (d) unstructured individual teacher interviews; (e) lesson observations; (f) artifact collection (e.g., photos to document the classroom-based and Museum artifacts); and (g) researcher's field notes as an observer and a participant.

The four teachers participated in three 2½-hour seminars led by the Museum educators and the science coach. These sessions were held at the Museum during the four months of the study. The Museum educator led the majority of the session and the science coach debriefed for the last 30-40 minutes. The role of the Museum educator was to provide resource knowledge, such as information about field trips, student learning opportunities, content knowledge (basic facts) and inquiry-based knowledge (questioning and exploring techniques). This information was shared with the teachers surrounding the objects, dioramas, and exhibit halls in the Museum. The role of the science coach was to provide curricular knowledge, such as how to make connections between the Museum exhibits and the scope and sequence topics for each grade level, alignment to state standards as exemplified on the Grade 4 State Science Exam, and pedagogical knowledge, such as how to integrate a museum trip experience into the classroom (i.e., pre-/during/post activities).

The first formal PD session at the school focused on building the trust of teacher participants, informing teachers of the Museum's role in this study, and administering a pre-questionnaire to ascertain the teachers' past experiences with science PD opportunities. The second session focused on identifying their pedagogical needs and concerns, Museum trip planning, and informing them of science education resources through the Museum and the National Science Teachers Association (NSTA) as an organization dedicated to the teaching and learning of science teacher development. Finally, the teachers were given an NSTA-published article on science notebooking and the city's core curriculum resources. The last formal session addressed how to organize and teach the use of science notebooks with students through examples and another NSTA-published science notebooking article. The teachers completed a post-questionnaire that assessed the effectiveness of the PD sessions and whether or not the teachers used the resources that they were given.

The first informal PD session at the Museum focused on how to engage in science inquiry in museum settings using observation skills and science notebooking. The second session was devoted to observing dioramas within exhibit halls. During the final session at the Museum, the team of four teachers developed student questioning techniques to critically observe a chosen diorama.

Primary and secondary data sources were combined to form layered descriptions of the effectiveness of the CDLN science coach/Museum mentoring model (Merriam, 1998). While the resultant descriptions focused on teachers' acquisition of science pedagogical content knowledge and Museum resource usage, the grounded theory methodology that was used cut across constructs in order to build a holistic description of the teachers' pattern of learning (Strauss & Corbin, 1998). In this way, there was no one-to-one mapping of data sources to construct what was learned from the formal and informal professional development sessions. For example, each source contributed one or more pieces to the overall description of how the coach and the museum educators influenced the teacher participants' development of PCK.

In this cross-case analysis of the four teachers, a grounded theory methodology was used in which three primary categories emerged from data analysis (Table 4.1). The conceptual categories were constructed from all audiotaped PD sessions, audiotaped interviews, and written questionnaires in which codes were defined to first identify properties or concepts. As the researcher, decisions about the categories and any embedded relationships were brought to light and defined throughout the analysis process (Charmaz, 2006). "In addition to categories, a [grounded] theory consists of two other elements—properties and hypotheses. Properties are also concepts but ones that describe a category; properties are not examples of a category but dimensions of it" (Merriam, 1998, p. 190).

After open and axial coding, seven properties were identified as actions teachers took in response to diagonal coaching, or the overlying core phenomenon. Table 4.1 illustrates the criteria for coding the seven corresponding properties and three major categories (the development of pedagogical content knowledge, knowledge and use of museum education resources, and increased teacher self-efficacy) using examples from data analysis.

Findings

The three major overlying themes that emerged were the development of pedagogical content knowledge (PCK), knowledge and use of museum education resources, and increased teacher self-efficacy.

Development of PCK (in Classroom and Field Trips)

The first category that emerged from this study was the *development of pedagogical content knowledge* or PCK. PCK development was defined by the following properties: understanding science content; awareness of new science teaching practices, such as planning and teaching inquiry-based science activities; awareness and use of science notebooks; development of standards-based activities in preparation for the Grade 4 State Science Exam; and modification of museum resources for their classes. Some comments from the teachers represent some of their learning within these areas:

Table 4.1. *Category Coding Scheme for Knowledge Acquisition/Classroom Connections Reported in Questionnaires, Interviews, and PD Sessions*

Major Coded Categories (Corresponding Properties)	Criteria for Coding Category/Properties
• **New Pedagogical Content Knowledge**	New acquisition of PCK as a result of the PD sessions. Includes verbal delivery of PD by facilitator and mention of importance or use of teaching methodology as a result of knowing the science content by a teacher (i.e., new science teaching strategies, using scientific vocabulary, knowledge of how and why to conduct FOSS or Harcourt investigations).
(Science Notebooking)	New knowledge acquisition as a result of the PD sessions. Includes verbal delivery of PD by facilitator and mention of importance or use of science notebooks by a teacher (i.e., Klentschy book, coach online resources, FOSS teacher guide resources, observed use in classroom).
(New Content Knowledge)	New content knowledge acquisition as a result of the PD sessions. Includes verbal delivery of PD by facilitator and mention of importance or use of scientific content by a teacher (i.e., use of science vocabulary, facts, terms, tools not known prior to PD).
(New Pedagogical Knowledge)	New pedagogical knowledge acquisition as a result of the PD sessions. Includes verbal delivery of PD by facilitator and mention of importance or use of teaching methodology by a teacher (i.e., new strategies, classroom techniques, alignment to state standards or city scope and sequence, knowledge of Department of Education resources, observed use in classroom of FOSS or Harcourt resources by a teacher).
(Inquiry-Based Science Activities)	New knowledge acquisition of hands-on inquiry-based science activities as a result of the PD sessions. Includes verbal delivery of PD by facilitator and mention of importance or use of a hands-on investigation or activity by a teacher (i.e., related curricular activities, questioning techniques while exploring, science notebooking).

Table 4.1 (continued)

Major Coded Categories (Corresponding Properties)	Criteria for Coding Category/Properties
• **Knowledge and Use of Museum Education Resources**	New knowledge acquisition of museum resources as a result of the PD sessions. Includes verbal delivery of PD by facilitator and mention of importance or use of museum resources by a teacher (i.e., articles, worksheets, tickets, teacher programs, website, online education guides)
(Inquiry-Based Science Activities)	New knowledge acquisition of hands-on inquiry-based science activities as a result of the PD sessions. Includes verbal delivery of PD by facilitator and mention of importance or use of a hands-on investigation or activity by a teacher (i.e., use of observation sheets in classroom lessons, questioning techniques while on Museum trip).
● **Increased Teacher Self-Efficacy**	Self-report of improved teacher confidence. Includes mention of science coach feedback as the cause of noted increase.
(New Pedagogical Content Knowledge)	New acquisition of PCK as a result of the PD sessions. Includes verbal delivery of PD by facilitator and mention of importance or use of teaching methodology as a result of knowing the science content by a teacher (i.e., new science teaching strategies, using scientific vocabulary, knowledge of how and why to conduct FOSS or Harcourt investigations).
(Self-Connection to Museum Resources)	The feeling of a connection or bond to the Museum space, events or resources (i.e., free ticket redemption with friends and family, Museum trip with class, knowledge and freedom to access Museum exhibits).
(Teacher-Teacher Collaboration)	New ability to connect with other colleagues (i.e. helping each other learn). Includes mention of idea exchange, lesson plan development support, and sharing of resource knowledge (i.e., location of FOSS/Harcourt teacher or student materials).

> I believe the scientific method was always a little unclear to me. The PDs helped not only to explain them further, but helped in explaining how they can be put into practice in the classroom and museum.
>
> …Yes, I've been able to begin some of the science notebook activities and tables and also realized I should use precise vocabulary! (graduate cylinder, volume, capacity) (Leah, Formal Post-PD Questionnaire)

> …I did learn about how I can better apply the science concepts that I already know. (Ada, Informal Post-PD Questionnaire)

When referring to the six essential characteristics of science learning in internships, Barab and Hay (2001) note that teachers' learning is participatory, happening "at the elbows" of more knowledgeable people such as a coach, a museum educator, and even one's peers. The teachers' acquisition of PCK through participatory science learning depends on who is facilitating the "learning internship"—in this case, both the science coach and the Museum educator. The participants in this study showed many indications of an increase in pedagogical content knowledge through participatory science learning in the diagonal relationships offered in the PD sessions. When a museum educator is the informal science liaison, PCK development can be seen in the comments made in a PD at the museum. For example, Leah mentioned:

> The workshops were helpful in clarifying concepts and questions students may have. The first workshop on Observations [was] extremely useful because it can be applied anywhere-outdoors, near school. (Leah, Informal Post-PD Questionnaire)

Another example is when Maria asked, "Are these animals stuffed or are these replicas?" (Maria, Informal PD Session #2) and in related comments during a class field trip. From both observations and interviews, Maria was overheard during her class museum trip explaining what Lillian had taught her to a group of curious students who wandered off to a nearby display case.

In addition, the way in which the Museum's resources were used in the teachers' classroom was another category established to code for PCK development. In Venus's classroom, her students observed organisms outside on a nature walk and filled out the Object Observation Sheet from an informal PD session (Figure 4.2).

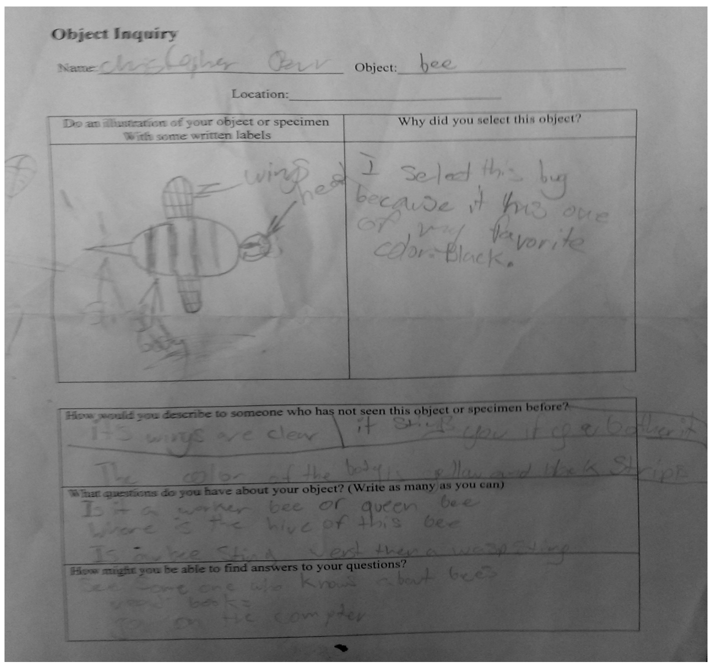


Figure 4.2. Object Observation Sheet (from Informal PD Session #1)
Used in Venus's Classroom on a Nature Walk

When the science coach was the expert teacher, there was a direct connection to PCK participatory learning in the classroom experience and connections between Museum resources and what the teachers were expected to teach in their classrooms.

Maria noted this relationship on two occasions and in both instances used what she learned from the coach and the Museum experiences with her students:

> When you came in, it was very helpful because I got to see a lesson that was not in the science kit, but it very much went with the unit we were studying. (Maria, Formal Post-PD Questionnaire)
>
> The way you organized the chart for children to track their learning was great. I used it when we were keeping track of the info for their field guides. [see Figure 4.3 for photograph of field guide chart Maria made] (Maria, Formal Post-PD Questionnaire)

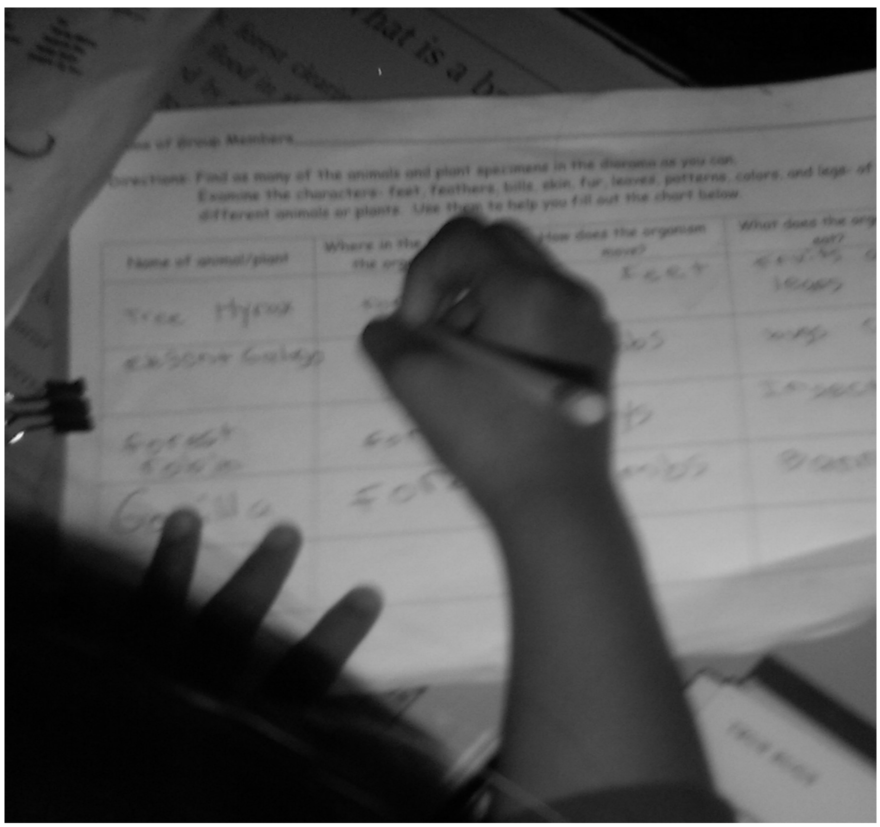


Figure 4.3. Maria's Class Field Trip:
Event Documentation-Student Worksheets (6/18/10)

Other instances of teachers' participatory learning from the coach-led PD were seen in the teachers' lesson execution. The diagonal link allowed the teachers' learning to be socially constructed through these informal and formal PD sessions. For example, Leah made a metric system resource display board for her classroom. This measurement poster and various scientific tools were used during a standards-based activity by her students (Figures 4.4 and 4.5). Similarly, Venus used a template for seed growth observations with her students (Figure 4.6). She also employed guided inquiry skills and notebooking. By instructing her students to record their observations and questions in their science notebooks, she led the students to develop their scientific wonderings, as Lillian had taught the teachers to do earlier in Informal PD session #2 when they created their own questions around a diorama scene set in an upstate region

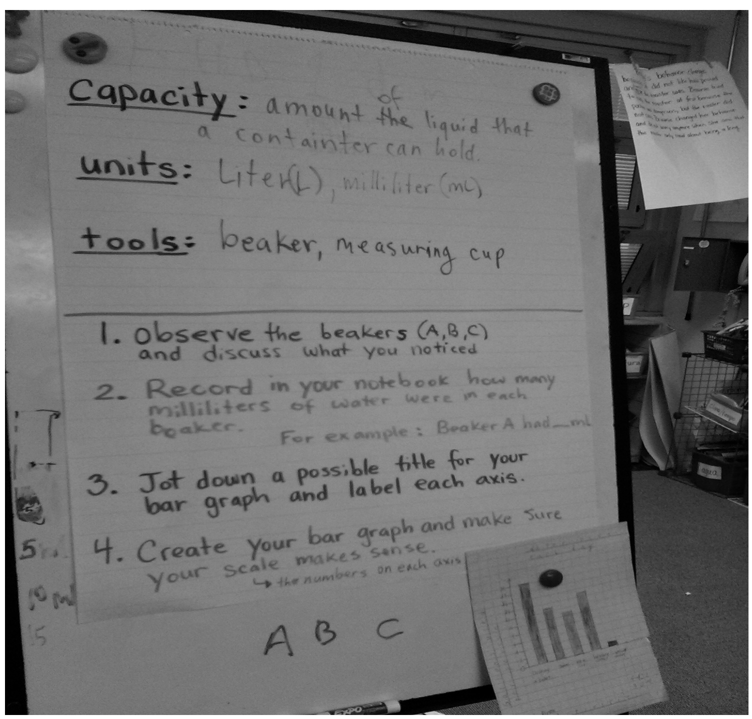


Figure 4.4. Leah's Classroom: Teacher-Made Chart—
Volume Lesson Vocabulary and Activity Directions (4/22/10)

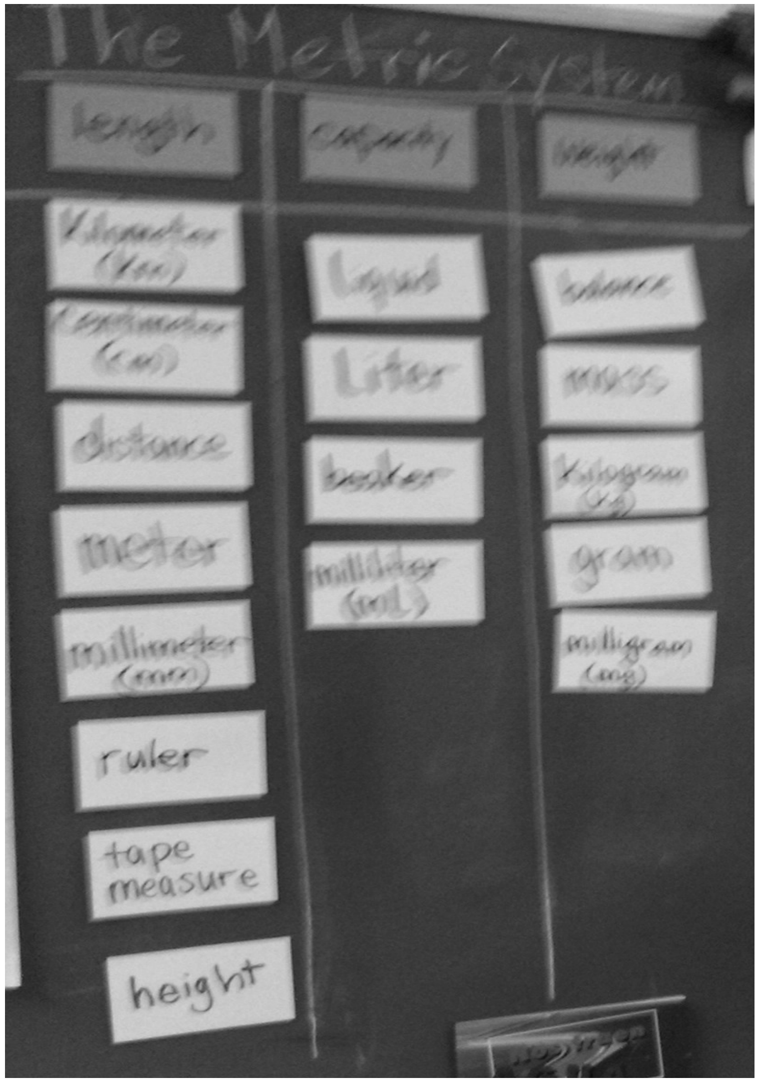


Figure 4.5. Leah's Classroom: Metric System Word Wall for Length, Capacity, and Weight (4/22/10)

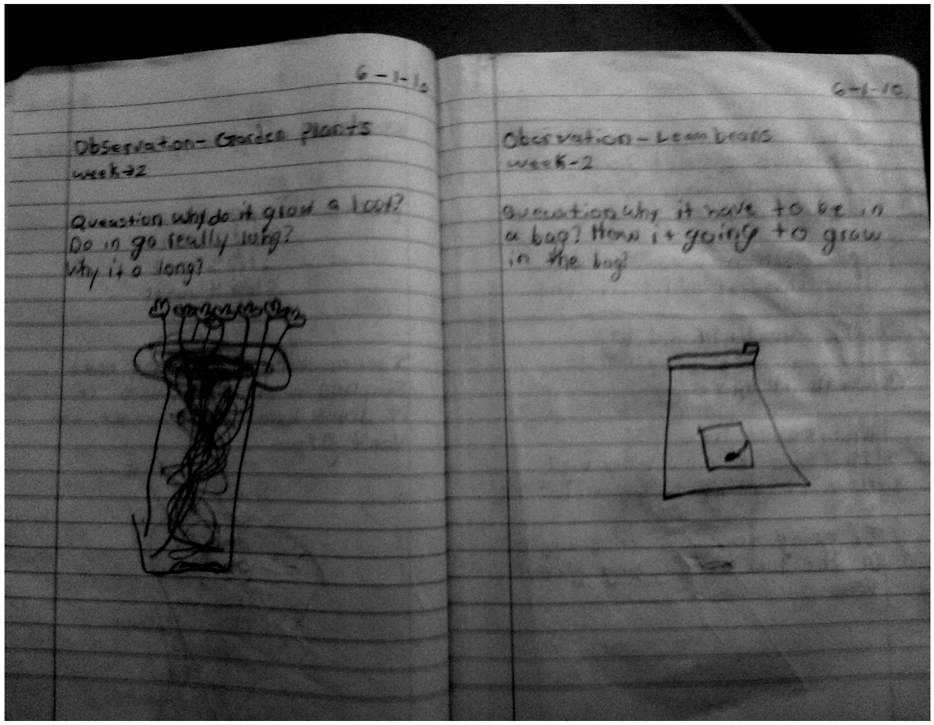


Figure 4.6. Venus's Classroom: Student Science Notebook Entry for the Observations of a Lima Bean Seed Grown in a Ziploc bag (6/1/10)

<u>Knowledge and Use of Museum Education Resources</u>

The second emergent category was knowledge of museum education. As Hein (2006) notes, museum education provides teachers with the knowledge to learn how to do inquiry-based activities, such as open-ended question development using multiple available resources (e.g., museum education materials or the actual Halls, dioramas, and exhibit spaces). For example, the teachers were shown the hidden gorilla in a diorama exemplifying camouflage and survival skills in a Rainforest ecosystem. The teachers in this study were given an enormous amount of PD in the field of museum education in three sessions. From the delivery of the informal PD, the teachers learned a great deal about several areas of teacher professional development that can be learned in museum education (see Table 4.2).

Table 4.2. *Museum Learning Professional Development*

Diorama PD	Forming problems, predictions, hypotheses, conclusions by observing the habitat
Museum Trip PD	Having students read the labels to get information, available Educator Guides
Inquiry-Based Museum PD	Planning alternate classroom activities, Science Notebooking
Participant-Directed PD	Having opportunity to visit/observe and implement learned skills when Museum educator gave teachers control of which space to visit
Content-Based Museum PC	Learning scientific facts about animals depicted in a diorama
Museum Physical Features PD	Learning about the evolution of the Halls, the history of museums, how dioramas are made, and definition of exhibit cases vs. dioramas

The statements of the science coach and the two Museum educators below exemplify three museum learning PD categories that form the diagonal link in the CDLN model. These examples serve to bridge informal with formal knowledge, skills and practices, and also highlight PCK skills and practices when using the Museum as a teaching and learning resource:

> Museum Trip PD: If you look at the Educator Guide—lots of the newer exhibits have Educator Guides. So, if you plan a trip with your students, they will send you this [shows Silk Road Guide to teachers] to you or you can even just get it online to be honest with you…. But to have a pre-visit kind of prepping your kids relating it to the topic and then having something focused for them to do…. Like literally, one or two things and for them to spend quality time [in Museum]. (Science Coach, Informal PD Session #1)
>
> Inquiry-Based PD: …when you're talking about…about size, have measuring rulers in your classroom [referring to Observation Sheet-Describing size of object using tools]. Have some of those little measuring things for clothing and stuff. Get the kids into thinking about the language and the clarifying language that they also need for math. But it also gives them a sense of size. (Violet, Informal PD Session #1)
>
> Diorama PD: In the question, problem and purpose section, the level of questioning is very simple. You open the diorama, and you ask yourself "How many, how long, how often, how much longer is blank than blank," this and that…. It's just basic information gathering, and you take it to a higher level, you know, same exhibit, "Which animals move the quickest? Which has the behaviors demonstrated?" Can you distinguish between male and female? What [characteristic] supports that?' (Lillian, Informal PD Session #3 in front of Deer Habitat Diorama)

As a result of these accounts from the PD sessions, the teachers were taught how to use museum resources on field trips with their students. Museum education was able to filter through in-class and out-of-classroom experiences through the partnership of the science coach, the museum educators, and the teachers in the study, otherwise referred to as the CDLN.

Self-Efficacy

The fourth category that emerged from data analysis was an increase in the self-efficacy of the teachers. The teachers developed the self-confidence to teach and act on science. This was due to the verbal praise by the science coach because the teachers successful executed an inquiry-based science lesson, and coordinated a class Museum trip by themselves. For example, Ada explained how the Museum-sponsored sessions assisted her in teaching science:

> I found them very helpful. Usually for a field trip, I look for online resources for what the class can do at the Museum. These workshops made me feel comfortable with coming up with my own plan for what the students can do based on their needs or what we're learning in class. (Ada, Informal Post-PD Questionnaire)

Teachers also had to feel a sense of confidence when it came to science teaching. The statements below by Ada exemplify the value of the science coach as a teacher mentor in the classroom and the formal PD sessions she led:

> I thought they were helpful. They made me feel like I was right on track with my science teaching, and showed me how I could improve upon what I'm already doing. (Ada, Formal Post-PD Questionnaire)
>
> In terms of teaching, it [science coach post observation feedback] gave me confidence in how I was teaching it. (Ada, Formal Post-PD Questionnaire)

Each teacher's ideas about her self-efficacy affected the activities chosen for student work, the process by which the work was executed, and their management styles (Bandura, 1997).

Based on the teachers' comments, an increased self-confidence to teach and act on science emerged from the data. Three corresponding properties illustrated the self-efficacy of the teachers: an increased knowledge base of PCK (i.e., feeling confident about where to find and effectively use resources from the Museum and the core curriculum FOSS program kit); a self-connection to the Museum; and teacher-to-teacher collaboration.

First, there was an increased knowledge base of PCK. The teachers became increasingly more confident and familiar with locating resources from the Museum and the core curriculum FOSS program kit. The acquisition of self-efficacy required the teachers to feel comfortable in their own individual way on the out-of-classroom trips they planned, as witnessed in the Biodiversity Hall at the Museum. During her class field trip, Venus was primarily concerned with class management and order; by contrast, Maria focused on completing the worksheet and exploring (Field Notes, 6/18/10 and 6/26/10). Thus, through informal PD conducted at the museum, two of four teachers (Maria and Venus) felt confident enough to plan a class museum trip to the Museum. The teachers used the science coach and online educator resources to prepare customized materials tailored to the needs of their own students (Figure 4.3).

Further evidence of developing PCK and conformity to it came in the form of instructional differentiation in the Museum and the classroom. For example, when Venus was planning her class field trip, she used the Museum worksheet during the field trip, but requested a Museum trip mini-unit developed by the science coach to help her plan the pre-, during, and post-activities in the classroom aligned to the city's scope and sequence (email correspondence, 5/16/10). The collaboration among the three components of the CDLN model led to a differentiated approach in planning the trip to the Museum and creating worksheets for students. This also aided in a more comprehensive planning and learning experience for the teachers and their students.

Second, there was a self-connection to the Museum. The Museum educators always extended a warm welcome to the teachers and encouraged them to visit either by themselves or with their class. The teachers formed individual Museum connections from participating in the informal PD sessions on-site at the Museum. They felt comfortable enough to now plan their own field trips without the help of the PTA, as was the school practice. An example of this was shown in Venus's statements made during the first in-school formal PD session:

> …the school PTA sets up like science trips for us. And I found out yesterday that although they're wonderful, it was difficult because I have to find a way…. How do we go on a trip…and like they had it, the Park Ranger came into our classroom. They [students] spoke to them. I want to say three weeks ago and they went on the trip and it was like chaos. Like chaos. Like I couldn't get them [the students] to focus. (Venus, Formal PD Session #1)
>
> The workshops were extremely helpful because they allowed me to get to know the Museum more personally. It was also helpful because it allowed my trips to be planned better. (Venus, Informal Post-PD Questionnaire)

When the planning and preparation of field trips were done by the PTA, the trips were not planned for learning, and thus created challenges for the teachers. These challenges caused teachers to become anxious over past informal science field experiences that were haphazardly inserted into the curriculum without teacher input. Venus and Leah mentioned their frustration with trips that did not have a specific learning focus:

> Venus: What do I do to have them [students], you know, focus them more when they're on a trip? You know, it's like, as if we never…
>
> Leah: Yeah, they need something to [do]it's as if they never went outside before! And that's how I felt. (Formal PD Session #1)

Lastly, teacher-to-teacher collaboration opened up new pathways for teachers to connect with other colleagues. For example, Leah told Ada about a website to download

Grade 4 exam practice questions (Researcher Field Notes, 5/16/10). Hence, the CDLN allowed for idea exchange and sharing of resource knowledge.

Discussion

The findings of the study indicate that the Collaborative Diagonal Learning Network (CDLN) enhances teachers' acquisition of pedagogical content knowledge through individual and joint mentorships with the science coach and Museum educators. The teachers exhibited three major learning characteristics that emerged from the data: development of pedagogical content knowledge (PCK), knowledge and use of museum education resources, and increased self-efficacy.

The first four hierarchical levels of PD evaluation identified by Guskey (2000) are presented in this study: (1) participants' reactions to the experience (e.g., increased self-confidence); (2) participants' learning from the experience (e.g., differentiation of museum and coach resources); (3) organizational support and change (e.g., support from principal to implement CDLN model); and (4) participants' use of new knowledge and skills (e.g., science notebooking, class field trips). While there is a fifth level, student learning outcomes, this is not addressed in the current study. Guskey mentions that this fifth level is too often the first area that policymakers want to address, without taking into account that achieving the previous four levels is critical for reaching level five. The focus of the current study examines the PCK of elementary teachers, particularly at levels 1-4.

The CDLN theoretical model establishes a framework for professional development. Using a multitude of data sources, the four teacher participants from this qualitative study provide a rich, coherent, construct-focused analysis for understanding how the CDLN allows an increase in elementary science. Although challenging to measure PCK, the findings of the study provide some evidence of its development. The four elementary teacher participants engaged in learning with the science coach, and the Museum educators, and actively participated in learning on-site at the Museum.

Specifically, the development of PCK by the teachers shows up in formal or classroom observations as well as informal learning in the Museum. By observing teachers in the classroom using the resources accessible to them from both informal and formal sources, the teachers put to use their knowledge, skills, and practices in learning science content at the Museum and connected these to the scope and sequence or FOSS kits, the City-adopted science curriculum materials. The teachers conversed with students in the classroom and on field trips about scientific content and museum learning, such as rainforest ecosystem preservation and diversity of organisms in Hall of Biodiversity, the bellybutton on the large whale in the Hall of Ocean Life, and the process for creating an animal model in the display cases.

PCK is shown to be a product of the mentor-mentee relationship, or science coaching, in both settings. The mentors represented here were the science coach who provided the formalized PD in the schools and classrooms of the participating teachers, and the Museum educators who provided PD in an informal setting. Both the science coach and the Museum educators acted as master coaches in a cognitive apprenticeship model (Collins, Brown, & Holum, 1991; Lave & Wenger, 1991). Coaching is a common theme that runs through the Collaborative Diagonal Learning Network. It is the positive perception of an instructional specialist as the bridge that supports a teacher-centered learning experience, as Collins, Brown, and Holum (1991) state:

> Coaching is the thread running through the entire apprenticeship experience. The master coaches the apprentice through a wide range of activities: choosing tasks, providing hints and scaffolding, evaluating the activities of apprentices and diagnosing the kinds of problems they are having, challenging them and offering encouragement, giving feedback, structuring the ways to do things, working on particular weaknesses. (p. 2)

Instructional coaching promotes opportunities for professional collaboration. A coach helps to increase the teacher's content and pedagogical knowledge (Hull, Balka, & Miles, 2009). Thus, coaches "are leaders of instruction and agents of change in school reform" (p. 50).

The CDLN is powerful because it creates a model for change in urban elementary reform through mentoring and coaching. Systems of education are normally resistant to deviations from the status quo. Yet given the current state of affairs of elementary science education, more is needed to address the teaching, learning, and professional development of teachers in elementary school (Mensah, 2010). In a large city, professional development itself can be considered an infrastrucuture with its own budget code and approved set of consultants. However, it is imperative that instructional coaches from all walks of life, including museums and schools, join forces to create a positive professional learning community with elementary teachers.

Implications

Most of the science education community has directed its attention to the nature of science, content knowledge development, and creating scientists as role models through teacher-scientist-museum partnerships (Melber & Cox-Peterson, 2005; Tanner, Chatman, & Allen, 2003). For instance, in 2001, the federal government initiated the Mathematics and Science Partnership (MSP) awards, five-year competitive grants to promote affiliations between colleges and universities and K-12 schools with the goal of improving students' performance in math and science (National Science Foundation [NSF], 2003b). This is indeed an important endeavor. However, without assessing the impact of the partnership to acknowledge its transferability to the classroom, it is a moot venture. The Collaborative Diagonal Learning Network (CDLN) model hopes to contribute to the transferability of PD models of informal science institutions (i.e., museums) to formal institutions (i.e., classrooms) and provide ongoing support in the form of the science coach. This model is particularly useful for elementary school programs, where elementary teachers lack the pedagogical and content support needed to teach science. It is imperative that informal science institutions and schools build capacity within science education. Museums and schools also need to change traditional practices of educating teachers as distinct entities separate from their mentors. In other words, schools must employ and make better use of science coaches to work within and outside of schools. Furthermore, rather than continue with the status quo of professional development offered to schools, models that are collaborative and bottom-up may provide the foundation on which to build strong science programs and strong teachers of science, particularly for elementary school settings.

Future PD programs and offerings may benefit from the implementation of the CDLN model where the science coach is an integral part of the diagonal mentorship and learning that the teacher receives. The science coach serves as the central tenet of the CDLN model where in-school support and real-life outside correlations are brought to the forefront of the educators' teaching and learning. For example, Joyce and Showers (1980) suggest that the outcomes of teacher professional development programs could be strengthened and sustained in part through educational coaching.

I argue that reform-minded professional development in elementary science education needs to be both intensive and sustained. The National Science Education Standards (NRC, 1996) call for more long-term, coherent professional development programs. Moreover, staff development must engage teachers in concrete teaching tasks and be based on teachers' experiences with students (Darling-Hammond, 1998). Supovitz and Turner (2000) demonstrate that PD undertaken in isolation from teachers' ongoing classroom duties seldom has much impact on teaching practices or student achievement. Lieberman (1995) goes further to argue that the definition of professional development must be expanded to include "authentic opportunities to learn from and with colleagues inside the school" (p. 591). The expanded definition of PD is exemplified in this research, whereby teacher-teacher collaboration was a finding. As a result, a small professional learning community (PLC) was formed during the formal PD sessions at Star Elementary. The PLC consisted of four teachers and a coach learning constructively from one another in a collegial space where they addressed their needs and shared best practices (Hord, 2009). For this reason, a science coach is needed in all schools to facilitate such PLCs, one who works with outside PD venues and models best teaching practices on site.

Conclusion

This study highlighted how professional development can broaden not only the teaching skills, but also the behaviors of elementary teachers who teach science. Through an understanding of science content knowledge as well as teaching and learning that encourage inquiry-based activities and professional learning, elementary teachers can become practitioners who are more self-confident in teaching science (Loughran, Mulhall, & Berry, 2004). The call for highly effective teachers by state and local districts emphasizes the need for better trained elementary teachers in P-12 education. Hence, the call for reform that the findings of this study suggest is the need for highly effective professional development within collaborative relationships such as the Collaborative Diagonal Learning Network (CDLN). If outside professional developers join forces to coordinate with in-house school support systems, the sustainability of the learned concepts and behaviors from the PD might be evidenced in student performance.

Chapter V

RESOURCES ABOUND! THE ACTIVATION AND USE OF INFORMAL SCIENCE INSTITUTIONS AS CULTURAL AND SOCIAL CAPITAL IN URBAN ELEMENTARY SCHOOLS

Abstract

This study examined how science coach and Museum-based professional development (PD) shaped the acquisition of teachers' awareness and practical use of informal science centers through a Collaborative Diagonal Learning Network (CDLN) model. This is a qualitative research study using a constructivist grounded theory methodology. The four participants were public elementary teachers who taught science on an average of once per week. The CDLN model pairs teachers with a coach and a Museum educator in order to provide science education PD in a formal and informal setting, respectively. Data were collected via PD sessions, classroom observations, researcher field notes, and interviews. Findings indicate that the CDLN model allowed elementary teachers the opportunity to gain new knowledge of cultural resources given by the PD facilitators to enhance their relationship with the Museum. However, the use of these resources was dependent upon their activation and transformation to cultural and social capital. The study findings have implications for reducing the achievement gap among elementary teachers in urban science education.

Keywords: Cultural Capital • Social Capital • Resources • Urban Science Education • Elementary Teachers • Informal Science Institution (ISI) • Professional Development

Introduction

Elementary teachers have little time and little desire to teach science lessons because of a lack of content and pedagogical resources. English language arts and mathematics are at the forefront of state and city accountability, while all other subjects are pushed to the back burner, with sometimes only half a period left in a week for instructional time (Knapp & Plecki, 2001; McCutcheon, 1980; Spillane, Diamond, Walker, Halverson, & Jita, 2001). Since hardly any time is allotted in the schedule for science instruction, there is also little left to allocate of materials and training resources. Teachers are in isolation, with no access to new ideas available to them through in-service professional development (PD), college courses, informal science institutions or their peers.

Informal science institutions offer teachers the resources and professional assistance that are sometimes needed for those working in urban schools and facing great challenges with limited available financial and material resources and inadequate PD (Melber & Cox-Peterson, 2005). Research that addresses informal science institutions shows that they have a long history of offering special programs for teachers at museums (Phillips, Finkelstein, & Weaver-Frerichs, 2007). Natural history museums are just one type of informal science center among many within the realm of informal education and cultural institutions, yet their impact is at the center of science teaching and learning outside of the traditional classroom environment. Museums offer teachers a unique opportunity to deepen their content knowledge and develop alternative methods to study the nature of science (NSTA, 1999).

I argue that although informal science education resources for instruction are limited in urban schools, teachers who are introduced to new ideas are able to activate them during instructional planning. The teachers' pedagogical content knowledge involves the creative revision and activation of these science resources, underscoring the fact that the mere possession of new resources does not automatically translate into their use during instruction without this activation.

This study contributes to the small but growing literature on contextualized teaching practices involving social and cultural capital in urban school settings. Unlike other studies (Lareau & Horvat, 1999; Monkman, Ronald, & Theramene, 2005) on social and cultural capital, this research does not examine class dimensions, class issues or social mobility, but rather access to teacher educational opportunities in science. This study investigates the conversion of human, social, cultural, and material *resources* to human, social, cultural, and material *capital*. The introduction of a science coach and museum educators (human resources), time to confer and meet together for PD (social resource), access to a large history museum (cultural resource), and available educational print and non-print resources (material resources) can allow elementary school teachers to coactivate an array of available resources and turn them into meaningful instructional tools that build capital (Lareau & Horvat, 1999; Rivera Maulucci, 2010). Specifically, cultural and social capital in which definitions are outlined in the study. Additionally, I address how these acquired resources brought about an increased knowledge base of information for teachers to use in meaningful ways in and out of their classroom during science instruction.

Theoretical Framework

Within the science education literature, the definition of informal learning is based on the context or setting in which it occurs. Definitions include “out-of-school” (Rennie, Feher, Dierking, & Falk, 2003) or “outside the classroom” (National Science

Teachers Association [NSTA], 1998), which imply learning obtained in a non-traditional environment or not in a traditional school/classroom setting. Likewise, for educators, informal learning can also imply professional development that takes place outside a school or district building. As NSTA (1998) states, “Informal science learning experiences offer teachers a powerful means to enhance both professional and personal development in science content knowledge and accessibility to unique resources” (p. 17). However, informal science institutions (ISIs) are underutilized for professional development in the general education community.

Phillips, Finkelstein, and Weaver-Frerichs (2007) surveyed 475 ISIs that provide support for K-12 science education, particularly in the area of teacher professional development. The researchers found that only 21% of the ISIs offer programs that provide coaching and classroom support and 45% offer collaborative partnerships. These findings call to mind that more PD programs should be developed for novice teachers with little or no pedagogical content knowledge in science who need both in- and out-of-school support (Meyer, 2004). There is indeed a gap in the literature focusing on the link between informal and formal teacher professional development because “ISIs may be missing key opportunities to partner with schools” (Phillips, Finkelstein, & Weaver-Frerichs, 2007, p. 1505). With a multitude of (mostly free) resources, ISIs are a forgotten link in the chain of teacher knowledge. Based on the theory of social constructivism, this paper hopes to address the potential for ISIs, such as natural history museums, to bridge elementary science education reform with the development of teacher-centered pedagogy.

In the connections to social constructivism, learners actively *construct* their own knowledge through group interactions. Social constructivism, as O'Loughlin (1992) states, focuses on a transformation model, where learning occurs because of the cognitive processes that the learner transfers and uses. Knowledge can be transferred from in-service professional development to use in the classroom. A teacher's knowledge for content and pedagogy is deeply rooted in teaching contexts where interactions, as described in this study, occur between three shared knowledge structures: teacher-teacher, teacher-coach, and teacher-Museum educator.

The Collaborative Diagonal Learning Network (CDLN)

Learning can be *situated* within informal and formal learning contexts (Lave & Wenger, 1991). As stated previously, three components make up a shared knowledge structure called a Collaborative Diagonal Learning Network (CDLN). CDLN is derived from organizational learning theory, in which Poell, Chivers, van der Krogt, and Wildemeersch (2000a) noted that employees in a work environment process and structure their learning within horizontal, vertical, and external learning networks. The network is a form of reference that can be used to describe the social framework of any organization where people are exchanging information and resources while interacting with each other. The vertical tie is more of a top-down approach by experts or specialists in the field. The horizontal tie is more "organic," where workers learn together and from one another. In the external tie, new strategies are initiated by outside expert professionals.

The CDLN joins the three networks or ties, thus bringing together formal and informal experts in the field—a science coach, a natural history museum, and teachers (Figure 5.1). The researcher developed the CDLN as a theoretical model to serve as a program model for professional development in elementary science reform. The CDLN includes a direct and sustained relationship between teachers and two science education experts through in-house workshops, demonstration lessons, teacher observations, and mini-institutes at an ISI. In a diagonal professional development model, novice elementary science teachers are provided with several resources to aid in their development of pedagogical content knowledge (PCK) (Shulman, 1986), identified through instruction in resource allocation via coach and museum-led workshops.

Social Capital

Social capital, as defined by Monkman, Ronald, and Theramene (2005), is composed of three distinct elements: form, shared norms, and resources. Form refers to the structure of social ties and the extent of the network. Shared norms are values and responsibilities. Resources include access to other social networks, relationships, materials, and information. The researchers explain that "relationships within social networks can be characterized in two dimensions: the strength of ties (strong or weak) and the shape or direction of the relationships (horizontal or vertical)" (p. 8). The strength of ties indicates the degree of closeness among the members in the network. Monkman and colleagues suggest that weak ties can actually "increase the likelihood of access to institutional resources and opportunities" (p. 8).

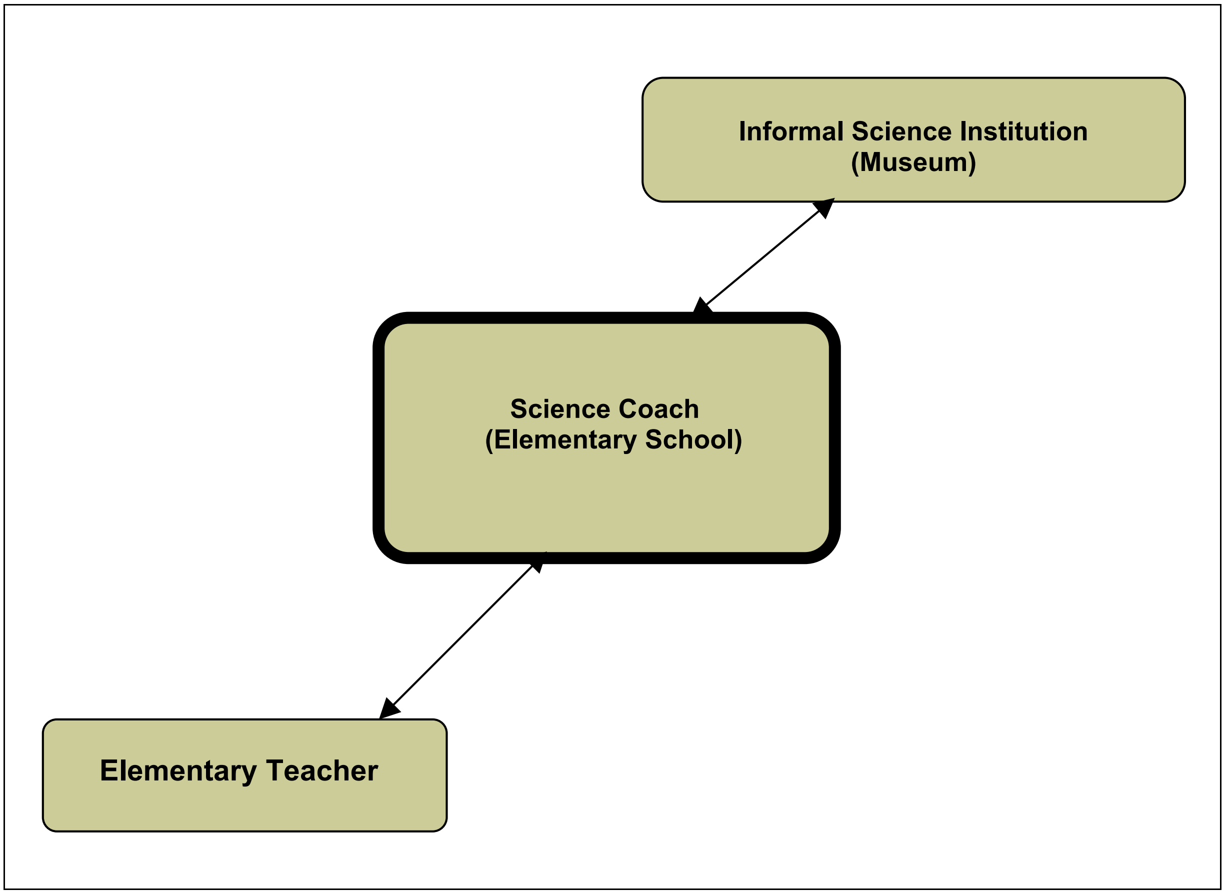


Figure 5.1. Collaborative Diagonal Learning Network (CDLN)—Theoretical Model for Interrelationship with Formal and Informal PD Providers

Social capital, as defined here, is the social relationships that develop through the knowledge and use of public materials made available by involvement in a diagonal network of science educators. While the horizontal direction of ties show peer-peer relationships and vertical show non-peers relationships through diagonal social linkages in the CDLN, individuals have the opportunity to access resources, socially construct their knowledge, and activate these resources, thus alleviating an intermediary step, and building social capital. The diagonal relationships allow all individuals (including the teachers in this study) to work together to increase teacher knowledge of informal science institutions and to build social capital.

Cultural Capital

Since Bourdieu (2011) coined the concept of cultural capital, many researchers have defined it in different ways, often labeling it according to the measurement tool they are using and what they believe it differentiates from in their study (Lareau & Weininger, 2003). Most have used the term "cultural capital" when referring to high status, class, style, taste, prestige, and behavior in relation to educational or even marital attainment. However, this study characterizes cultural capital, as defined by DiMaggio and Mohr (1985), as "interest in and experience with prestigious cultural resources" (p. 1233). Distinguishing features of cultural resources are activities that were open to those of high status, such as visiting museums and cultural centers, and assessing information about classical literature, music, and the arts. This study also agrees with Lareau and Weininger (2003) who argue that they "have attempted to develop an alternative interpretation of cultural capital that does not restrict its scope exclusively to 'elite status cultures,' and that does not attempt to partition it—analytically or empirically—from 'human capital' or 'technical' skill" (p. 597). Here, cultural resources as cultural capital are defined as information about science gathered from informal learning activities in "artifact and collections-based institutions," such as a natural history museum (Leinhardt & Crowley, 2001, p. 2). Moreover, information about science is delivered via the human capital within the Collaborative Diagonal Learning Network, identified as the science coach and museum-based educators.

Methodology

Research Design

A constructivist grounded theory methodology (Charmaz, 2006; Strauss & Corbin, 1998) was used as the research paradigm to examine formal-based (classroom) and informal-based (museum) professional development due to the cyclical nature of the theoretical CDLN model under study. Since the PD had a four-month span of data collection, the researcher was able to gather, analyze, and turn to other sources to form open codes and general patterns that emerged at different stages of the coding process. Using the theoretical CDLN model as a backdrop to the research design, this qualitative study was driven by one overall question and two sub-questions:

- How does the CDLN model enhance elementary teachers' awareness and practical use of informal science centers?
    a. In what ways does *science coach mentoring* enhance elementary teachers' awareness and practical use of informal science centers?
    b. In what ways do *museum-based workshops* enhance elementary teachers' awareness and practical use of informal science centers?
    c. In what ways do the *science coach and museum-based workshops* enhance elementary teachers' awareness and practical use of informal science centers?

Setting

This study took place in two different settings: a public elementary school, Star Elementary (pseudonym), and a large natural history museum, the Museum (pseudonym). In this study, the school and the members of the school community are referred to as "formal" educators, while members of the Museum are referred to as "informal" educators. Both field research settings occur in a large urban city, hereafter referred to as "City."

Star Elementary is ranked as a developing school, according to an analysis tool called a Quality Review that the City's Department of Education uses to evaluate schools (New York City Department of Education [NYC DOE], 2010). The demographics of the 483 PreK-5 student population consisted of 4% Asian, 21% White, 25% Black, and 45% Hispanic. Some families live in public housing projects while others live in multimillion-dollar apartment buildings. The extremely active Parent Teacher Association (PTA) takes great pride in its large budget thanks largely to the famous and prominent parents whose children attend the school. In addition, the PTA has well-attended fee-driven family events that the school holds. Due to great fundraising, the PTA is able to coordinate and schedule class field trips, such as the Urban Park Rangers, albeit without the input of the class's teachers.

The Museum is one of the largest natural history museums in the world and is located only 12 blocks away from Star Elementary School. Despite the relatively short distance between the two learning institutions, there is no connection or collaboration between the Museum and the school. The Education Department at the Museum uses the exhibits and halls as a teaching tool for learners of all ages, especially public school teachers; yet Star Elementary has not utilized the Museum for PD or field trips to augment the City-endorsed science curriculum (Harcourt and/or Full Option Science System [FOSS]; NYC DOE, 2008). The text and kit-based programs that follow the City's scope and sequence that it has adopted is divided by grade and unit, and several museum halls and exhibits can complement the science curricula.

Participants and Professional Development Cycle

The study was conducted with four elementary teachers, two museum educators (informal PD facilitators), and one science coach (formal PD facilitator), using a professional development cycle in both informal and formal settings. The informal PD facilitators were Violet, a Museum educator who conducted the first session, and Lillian, a Museum educator who conducted the last two sessions (pseudonyms are used for all study participants).

First, the four teacher participants were purposefully sampled by Principal Dash (pseudonym) of Star Elementary. She purposefully selected the four teachers based on a diverse group of educators representative of the school's staff and student population. The ethnicity, demographic data, and teaching experience of teacher participants were collected. A brief profile of the teachers is presented below (pseudonyms of teacher participants were chosen by the teachers themselves):

- Leah, a 4^{th} grade English Language Learner (ELL) teacher; Ecuadorian, 25 years old, two years teaching (teaching fellow).

- Ada, a 3rd/4th grade Special Education teacher; Indian-American, 27 years old, four years teaching.
- Maria, a 2nd grade general education teacher; Dominican, 25 years old, four years teaching.
- Venus, a 3rd grade general education teacher (who has served as the school science liaison since the passing of their science cluster teacher a few years ago); Greek, 30 years old, five years teaching.

Hence, the four teachers were diverse, mostly young novice elementary teachers who serviced a broad range of grade levels and student learning needs.

The research cycle took place over four months with three informal and formal workshop sessions. The PD sessions were facilitated by one of three science education experts. The teacher participants were involved in the following PD activities:

- 3 formal content and lesson-focused PD at school meetings
- 3 informal PD sessions at the Museum
- pre- and post-observation conferences at school facilitated by the science coach
- demos/co-teaching/lesson observations conducted by the science coach

The professional development cycle of the Collaborative Diagonal Learning Network (CDLN) consisted of three 2½-hour informal PD sessions led by Museum educators and the science coach held at the Museum from March to June 2010. The Museum educators led the majority of the sessions and the science coach debriefed for the last 30 minutes. The role of the Museum educator was to provide resource knowledge, for example, on field trips and provide online educator information and related science education articles. The Museum educator also provided content knowledge and basic scientific facts about artifacts and collections in the Museum, inquiry teaching, questioning techniques through the use of science notebooking, and building observation skills and strategies for the objects, dioramas, and exhibit halls in the Museum.

The science coach conducted the formal PD sessions using a traditional coaching definition. As described by Hull (1999), a science "coach is an individual who is well versed in [science] content and pedagogy and who works directly with classroom teachers to improve student learning of [science]" (p. 3). Thus, in addition to what the Museum educators provided for the teachers, the role of the science coach was to provide curricular knowledge of how the museum exhibits can connect to the scope and sequence topics for each grade level, how to align lessons with State Standards, and how to prepare students for the Grade 4 State Science Exam based on the museum resources, exhibits, and halls. In other words, the science coach provided pedagogical support and knowledge for the teachers. The coach also showed the teachers how to integrate a museum trip experience or science notebooking into the classroom and to discuss related science education articles to build teachers' PCK.

Data Collection and Analysis

The primary and secondary data sources included: (a) audiotaped PD sessions; (b) open-ended pre-/post-questionnaires to assess the effectiveness of the PDs and whether or not the teachers used the resources; (c) audiotaped semi-structured group teacher interviews; (d) semi-structured individual teacher interviews to gauge teacher PD needs; (e) lesson observations; (f) artifact collection (e.g., photos to document the classroom-based and museum teacher-made artifacts); and (g) researcher field notes as an observer and a participant (see Appendices A-C).

Primary and secondary data sources were combined to form layered descriptions of the effectiveness of the CDLN model (Merriam, 1998). Data sources, when audiotaped, were transcribed and then analyzed using the constant comparative method (Charmaz, 2006). By applying a constructivist grounded theory methodology, codes and general patterns emerged using the theoretical CDLN model as a backdrop to the research design. To enhance the trustworthiness of the data analysis, investigator triangulation of multiple data sources was employed. In this way, there was no one-to-one mapping of data sources to construct; rather, each data source, whether primary or secondary, contributed one or more pieces to the overall description of the teachers' acquisition and use of cultural resources (Strauss & Corbin, 1998).

For example, in the process of coding for resources, the teachers mentioned cultural resources through diagonal ties between themselves and the PD facilitators. Using the constant comparative method across the data sources, the participants mentioned various educational materials and these references were coded under the category *museum resources,* including: museum education articles, inquiry-based worksheets, tickets, teacher programs, *Resources for Learning* website, and education guides to exhibits and halls. These served as examples of cultural resources from the museum that allowed the teachers to build their social and cultural capital.

In another example, the category *self-connection to museum* emerged after chunking and coding the Informal PD Session #1 transcript. The Museum educator asked if the teachers ever visited the Museum on their own and, if so, to describe any memorable experiences. In another primary data source, Formal PD Session #2 transcript, the science coach asked the teachers if they used the free set of Museum tickets given to them and which exhibits/halls they toured. Codes such as "foods in my culture," "museum to museum connection," "visited when I was young," and "visited with friends" were identified.

The category *increased pedagogical content knowledge (PCK) in informal science education* was developed after the teachers made distinct connections between exhibits and City curriculum topics, either during question development during Informal PD Session #3 or as an artifact, such as a revised observation sheet for their science lessons. Lastly, *museum trip planning* was identified as a category when teachers took the opportunity to bring their students on a unit-related excursion and when they revised a student museum trip worksheet for an exhibit.

Elements of rigor were used in this study, such as peer debriefing and member checks when coding, categorizing, and confirming results with teacher participants. These verification strategies ensured both reliability and validity when used concurrently while collecting and analyzing the primary and secondary data sources (Guba & Lincoln, 1981; Lincoln & Guba, 1985; Morse, Barrett, Mayan, Olson, & Spiers, 2002).

Findings

The data analysis revealed that the teachers were able to enhance their awareness and practical use of informal science centers through the science coach and the Museum educators. The teachers acquired and used a variety of instructional resources from the Museum. Furthermore, the analysis showed that those instructional resources were activated and translated into cultural and social capital, mostly due to the following characteristics of the elementary teachers: (a) knowledge of existing Museum resources; (b) self-connection to the Museum; (c) increased pedagogical content knowledge (PCK) in informal science education; and (d) Museum trip planning.

Building Social Capital: Knowledge of Museum as Cultural Resource

Many teachers in the large urban city where the Museum and Star Elementary are located were unaware that museum admission was free to public school children. For example, Venus expressed her happiness with the PD for informing her of the no-cost admission for her class:

> I didn't even know that the programs were free for the kids. I thought they had to pay for them. So that added a challenge. Now, that I know they're free, that's fine with me. That makes it so much easier, you know?

A huge financial hurdle was overcome when deciding to plan a trip with students, many of whom lived in public housing and were unable to afford a general admission price for children of $9. The coach even informed the teachers that the general admission price was only a suggested one; therefore, teachers would pay what they were willing to donate when visiting on their own again. In the end, the human resources—the science coach in this case—alerted teachers to the money-saving free admission and built up their social capital of communicating with their students and others within their social network on how accessible the museum was for them.

The participants and facilitators in the CDLN had various roles, vehicles, and mechanisms for translating cultural and material resources into social capital. For instance, teacher-to-teacher collaboration, curricula alignment, and museum tours were three of the many ways that teachers benefited from knowing more about the museum. As shown in Table 5.1, data revealed different attributes of expectations for structure, shared norms, and access to resources to bring about social capital. Evidence for this summary chart was derived from both the researcher's field notes and the informal and formal PD sessions conducted with the teachers.

Self-Connection to Cultural Resources

The teachers not only had to establish a level of trust with the human resources or the two PD facilitators, but also the cultural resources that the Museum had to offer. This was in essence the substance of the CDLN model. A huge building, the Museum is one of the largest cultural institutions in America encompassing four city blocks. Hence, a certain level of comfort with the Museum was established early on to generate a welcoming tone and make the teachers feel as if they were part of the education community within the Museum, as told here by the Museum educator, Violet, at the beginning of the first informal session:

Table 5.1. *The Evolution of Social Capital in the CDLN Model*

Form: Structure of *Social Ties*	Shared Norms (values and responsibilities)	Access to Human/Cultural/Material Resources
Teacher's social network in PD is collaborative and collegial. They draw on each other in many roles (for help, as an audience, etc.). *Horizontal, Strong*	They are expected to rely on and help each other in the classroom to troubleshoot, offer advice about inquiry-based science lessons, etc.	Horizontal ties (among teachers) provide an opportunity for a PLC to form (i.e., peer dialogue, sharing ideas).
Science coach acts a support for a scaffolded experience, but also strategically introduces new material, ideas. *Vertical, Strong*	Science coach acts as supporter, facilitator when needed, to help teachers become successful in science lessons.	Science coach represents one vertical tie, and many more resources become available if the teacher chooses to use them (i.e., syllabus, state exam, articles, demos, co-teaching, critical feedback, museum trip info, etc.)
Museum educator acts as support for a scaffolded experience, but also strategically introduces new material, ideas, and resources. *Vertical, Weak*	Museum educator acts as supporter, facilitator when needed, to help teachers become successful in science lessons.	Museum educator represents one vertical tie, and many more resources become available if the teacher chooses to use them (i.e., tickets, worksheets, articles, books, online tools, museum trip info).
Teachers, science coach, and Museum educator act as a support network (CDLN) to bridge multiple resources. *Diagonal, Strong*	All act as supporters when needed and expert mentors and facilitators.	All represent a diagonal tie that acts in concert to give and enact resources.

Adapted from Monkman, Ronald, & Theramene, 2005, p. 23

> Well, I hope that with the three sessions that we have here that, number one we will get you hooked and, number two you will see this place as your place-as an extension of your classroom, whether it's for you to come check out some stuff or whether it's for you to come and observe other people. You know you're our neighbors and we see people from all over the world and we drag people from all over the boroughs. So I like it when [Natasha] said she really wanted to work with some schools that will eventually be an access and a resource for teachers. (Violet, Informal PD Session #1)

The feeling of being welcomed by the Education Department was conveyed by Ada when asked if she would come back to the Museum on her own:

> Yes, I enjoy going to the museum personally and feel like I still have a lot to explore. I also would love to take my class because I think they would love it and also learn a lot from it. (Ada, Informal Post-PD Questionnaire)

The self-connection to the Museum was also established during the first part of the formal and informal PD sessions when the science coach and the Museum educator gave out free tickets for general Museum admission and to visit a special traveling exhibit. Taking a spouse or a friend with them, all the teacher participants visited the Museum the following month. Three out of four had never been to the Museum in over five years, and Ada who visited the previous year tried to see everything but ended up with a jumbled view of what the Museum had to offer. However, on a recent visit, Ada and her friend looked at the Elephant diorama and recounted their student-like reactions:

> When I went with my friend over the weekend, she's a teacher too, and she was like, "We could actually react how the kids are." You could be like, "ewwwww," or whatever. When you're with the kids, you can't-you have to be like, "Oh no, that's just dung!" (Ada, Formal PD Session #3)

During the PD, Violet suggested that everyone visit a few exhibits and halls and strategically look at and return on a different day to see others. She suggested that they visit "a little at a time." The science coach also agreed and the teachers later followed that advice, not only on their personal tours but when two teachers (Maria and Venus) returned with their classes on a purposeful field trip.

Cultural Resources for Increasing Pedagogical Content Knowledge

Not only did the teachers have a social network of support for each other, but the PD facilitators helped teachers be successful with connecting the Museum's resources to the science classroom activities they struggled with, for instance, how to use worksheets and what to do with students on a field trip. The Object Observation sheet was one tool modeled by Violet during the first informal PD session where she invited teachers to try it out themselves. The teachers had access to a cart-full of limited free-choice objects to observe, such as stuffed local birds, shells, and butterfly specimens.

The science coach was a vehicle for bridging the learning from the informal session with the agenda of the formal sessions. Leah mentioned that the Object Observation sheet was a helpful resource to incorporate into a science notebook, which the science coach had suggested:

> They were extremely helpful in clarifying the units of science covered in the fourth grade. Preparation for the state test helped as well as the science notebook/observation sheet example. (Leah, Formal Post-PD Questionnaire)

Venus also referred to the worksheet in an individual interview with the science coach, when she mentioned that she liked that students can "sketch, talk, and write about questions that they have. I can relate it to the Central Park trip [a PTA planned trip with the Urban Park Rangers] and notice the similarities and differences and use it in the garden outside in front of the school and I'll use it again when we go to the museum" (Venus, Individual Interview).

Similarly, the informal sessions at the Museum were very beneficial to the teachers as they received direct feedback on how to use the Museum and make accommodations for diverse students. For example, an explanation of how to use the Museum resources with ELLs was modeled by Violet:

> So the observation, the description, and conversation. Now with little kids…. Now who has the youngest? The first/second graders? [Maria raises her hand]. Okay. With little kids or even when you get to the fourth grade, there's the business of drawing and sketching. And how many of you have new English Language Learners in your classes? [All raise their hands] Everybody, right? And you have one or two or three kids always or you have large numbers. So there's a whole question of drawing or seeing real things or picking up—especially touching something that it's really real. It's really important because even if they cannot tell you in their other language, they know what it feels like. They know the real size of something. So conceptually they're getting it. They might not be able to tell you what it is and that's why you model it in that other language. You do it more in conversations…. So, there's a lot of…it's a different [Venus: Like a scaffold] interaction. You have to scaffold but you also have to give them the words [Venus: Right]…. So that scaffolding is really going to be important and especially with museums and objects. (Violet, Informal PD Session #1)

The excerpt above from Violet was just one example of how the Museum facilitator's instruction developed teachers' PCK and showed them how to deepen their inquiry skills, use scientific artifacts, and provide enough scaffolding for students of diverse learning abilities. Several levels of communication were occurring among each member of the CDLN that caused everyone to help each other to solve pedagogical content knowledge issues and acquire help from other resources made available to them by the science coach and/or Museum educator.

The participants' reactions, reflections, interpretations, and/or uses of what was presented to them in the PD sessions aided in the development of PCK. The reflections also allowed them to view the Museum as a cultural artifact to learn more about science. For example, Leah reflected on the value and impact that the informal PD had on her views of dioramas. She recognized that she did not know how to look at the life-like dioramas. Leah admitted that she rarely viewed every element of the diorama as a visitor but as a teacher learner, she now recognized that objects in a display represent examples of pedagogical goals (Leinhardt & Crowley, 2001). Dioramas were displays that she passed by and never truly studied for what they were-a moment captured in time:

> I felt like I myself looked at it and maybe like walked by. Like, "Oh, look at that; that's cool." But never for a second thought about background. I think that was probably the most eye-opening thing you pointed out.… Thinking about my kids, they'd probably just slide by that too, you know? (Leah, Formal PD Session #3)

In other examples, questionnaire responses from Venus, Ada, and Leah also exhibited development of Museum PCK. When asked what new science concepts they learned, how helpful the Museum-led workshops were, and what Museum resources would they use with their classes, these teachers responded with ideas to enhance student learning in the Museum as well as their teaching of science using the Museum and its resources:

> Formulating questions, hypotheses, and predictions according to dioramas and observations in the museum and how to build on student responses…. It allowed me to connect observations and teaching with the museum trips. (Venus, Informal Post-PD Questionnaire)

> Yes, they [Museum workshops] not only gave me ideas for when I bring a class to a museum, but also things I can do in a classroom. For example, ways to have them observe or analyze a picture, object, etc. (Ada, Informal Post-PD Questionnaire)

> Yes, there were several exhibits (Hall of Biodiversity, North American. Mammals, Ocean Life) that were connected to the current curriculum and interesting…. Educator's guides for the Hall of Biodiversity, Ocean Life, and Eastern Woodlands. (Leah, Informal Post-PD Questionnaire)

> I usually look at online resources to see if they are relevant to what we're doing as a class. (Ada, Informal Post-PD Questionnaire)

As Rivera Maulucci (2010) notes, "teachers need help filling gaps between kits, texts, their science and pedagogical knowledge, and their science teaching" (p. 857). She recommends, much as this research also recommends, that future studies "examine development of social networks" (p. 857) and their inherent structures and synergy necessary for improving science education reform. The foundation provided here by the science coach and museum-based facilitators allowed for a new social construction of knowledge that came from a variety of collaborative sources, including other teachers and print and non-print resources.

Cultural Capital in the Museum

Cultural capital is acquired by demonstrating membership through the proper use of cultural resources and the means to gain entry (Monkman, Ronald, & Theramene, 2005). In order to develop strong ties between all members of the CDLN, the science coach gave the teachers two sets of admission tickets to the Museum at the end of the first and last informal PD sessions. Expressing their eagerness and excitement to tour the Museum with their family and friends, all four teachers visited within four weeks of the first PD session. Their "private" visit to the Museum gave the teachers an opportunity to put into practice what they had learned from the formal and informal sessions. This was also an opportunity to bring together social, cultural, and human resources in their visit to the Museum.

For example, in their group interviews with the science coach, Maria and Leah noted that they were elated to act as Museum-instructors when visiting the Museum with friends. Maria pointed out the "whale carcass" and "tubeworms" to her own friends that she remembered talking about during PD. Leah reflected on two aspects of the informal PD sessions: self-connection to museum-based PD and free access to an informal science institution. Leah reflected after her visit with friends that she was more encouraged to make a return trip, but sharing the experience with her students, as she alludes to here: "it was memorable for me. It's something that I immediately wanted to go back and spread with others. And I feel like it's worth working through with kids just to get them…going back. And it's nice when it's suggested donation" (Leah, Formal PD Session #3).

These examples translate cultural resources into cultural capital. All teachers expressed a desire to not only go back on their own, but also to take their students with them. Prior to their personal visit to the Museum, taking their students to the Museum was not an option given their recent excursion to Central Park with the Urban Park Rangers, a nature walk planned by the Star Elementary PTA. The approach the Park Ranger used to engage the children troubled Venus because she felt that the students were not concentrating on the task at hand. The students were expected to use binoculars to view the different birds in the habitat and chaos ensued in trying to do so. Instead, Venus wanted a way to organize the trip to maintain control. She talked about the post-Museum trip experience when the students returned to the classroom:

> …we came back to class, I want to say a handful could tell me what they learned and everybody else and no clue. More so, the issue was, what do I do to have them, you know focus them more when they're on a trip? You know it's like, as if we never… [Leah: Yeah, they need something to do.] …went outside before! And that's how I felt. (Venus/Leah, Formal PD Session #1)

In addition to Venus and Leah requesting guidance on activities for the children to preserve what they learned, Maria pointed out that the in-school and out-of-classroom connections were too spaced out for the PTA planned field trip. It was hard for students to retain knowledge over three weeks: "There's a big disconnect. Maybe it should be the day before or that week" (Venus/Maria, Formal PD Session #1).

As a result of past unprepared field experiences, the teachers expressed anxiety over the chaotic and poorly planned trips, but they also expressed interest in learning how to properly execute a well-thought-out museum trip. As a consequence, in an email on May 16th, Venus requested a museum trip mini-unit lesson plan template created by the science coach. The mini-unit would be used to assist teachers with setting up their pre-/during/post-activities at the Museum. She wanted to address the challenge of class management. Foremost, the structured nature of the mini-unit also aided Venus to appropriately plan, schedule, and differentiate the Object Observation worksheet to meet the needs of her teaching style and her third graders. Thus, lesson planning using the mini-unit aided Venus, in particular, to be ready for her June 14th Museum field trip. Similarly, Maria, when planning her June 18th class trip to the Museum, revised the Educator Guides that the Museum produces to make them more suitable for her second grade class (see Figure 5.2):

> You know the Hall of Biodiversity? They gave you a packet, and that little thing that we went to, the rainforest; they had like questions asking the kids, but the problem is my kids are eight. And so, I put the questions in a chart form. And so, I gave them a paper with the names—all the animals, and then I made a chart. (Maria, Formal PD Session #3)

While encouraged by the science coach during the four months, two teachers took it upon themselves to schedule and actively plan a focused museum trip to the Museum. The trips aligned with their current unit of study: Venus, Grade 3, "Plant and Animal Adaptations" correlated with the Frogs Exhibit, and Maria, Grade 2, "Plant Diversity" correlated with the Hall of Biodiversity. Thus, by coordinating an informal learning experience for their students, these two teachers activated their cultural resources and turned them into cultural capital.

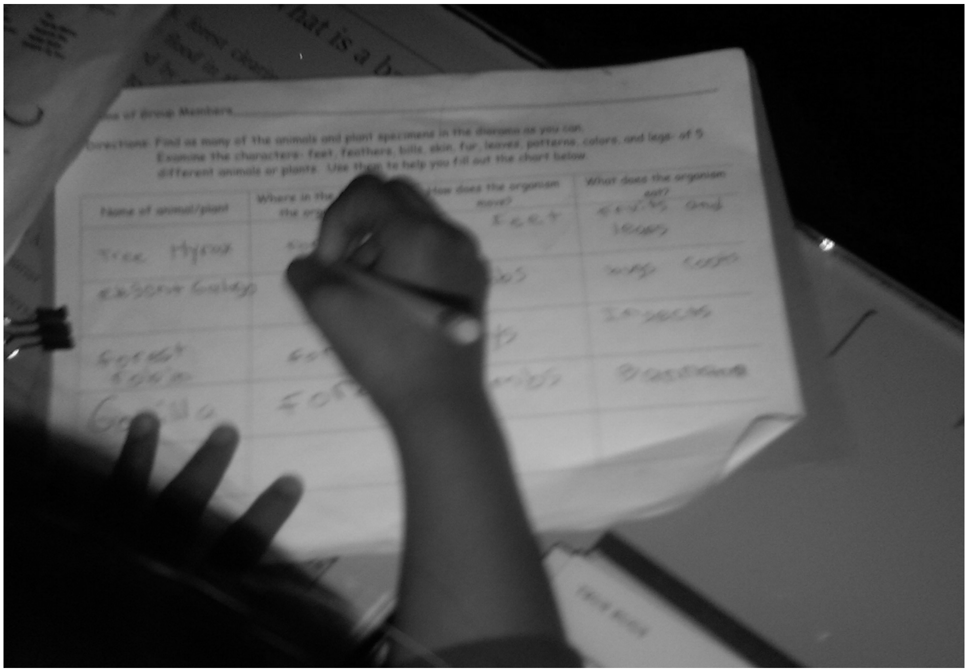


Figure 5.2. Maria's Class Field Trip: Event Documentation—
Student Worksheet (6/18/10)

Discussion and Implications

The following four categories of elementary teacher learning that transferred into cultural and social capital were: (a) knowledge of existing museum resources; (b) self-connection to museum; (c) increased pedagogical content knowledge (PCK) in informal science education; and (d) museum trip planning.

The findings of this study suggest that making cultural institutions, such as museums and their resources, accessible to teacher and students through a diagonal model of professional development will avail them of opportunities for cultural and social capital to be activated. For example, "Museums are places where the objects and messages have been selected as ones of high cultural value" (Leinhardt & Crowley, 2001, p. 3). Housed in museums are collections of objects and artifacts displayed in systems, subsystems, and interactions between the two. However, it is up to the classroom teacher to demystify the art, design, and language of the display and the corresponding label telling its story; and it is up to the school liaison to facilitate this teacher/student learning between schools and museums.

Elementary teachers are agents of change as they transform cultural resources (i.e., museum objects, museum exposure) into cultural capital for children in large urban areas. Through the Collaborative Diagonal Learning Network (CDLN), the science coach, Museum educators, and the teachers supported one another to ensure that both teachers and students were exposed to the educational resources that informal science institutions, such as the Museum, have to offer. Through the chosen setting of the informal PD and free tickets, the teachers gained entry into the Museum. Through text and non-print resources such as articles, Educator Guides, and websites, the teachers gained insight into how to relate the objects to the science curriculum. Through tours, advice, resources, and encouragement, the two teachers enacted their cultural capital and planed a Museum trip for their classes, subsequently opening the doors of the Museum to their students who mostly reside just blocks away but have not taken advantage of the cultural institution in their own backyard.

These social networks of teachers might provide them with access to useful information or resources with which to enhance their school's or classroom's instructional program, resources that would not have been accessible to the school without these connections (Spillane, Diamond, Walker, Halverson, & Jita, 2001). Social capital also refers to information and resources that are part of social relationships that go beyond the school. The Museum as an institution offers the teachers a wealth of new information and resources to supplement the City's science curriculum. The CDLN provides the teachers with an affiliation that extends beyond the school grounds to the Museum and to valuable human and social capital.

Research shows that teachers have certain factors impacting upon them that prevent them from not organizing and planning field trips: a lack of teaching skills, a disjoint between theory and practice, and a lack of resources (Michie, 1998; Orion, 1993; Price & Hein, 1991). In-service PD programs in large urban city settings must focus on the enhancement of teachers' science teaching skills and help teachers to develop and change these skills to work with all students (Atwater, 1995). The National Research Council (NRC) (2009) suggests "that informal environments for science learning may be particularly effective for youth from historically nondominant groups—groups with limited sociopolitical status in society, who are often marginalized because of their cultural, language, and behavioral differences" (p. 301). When cultural institutions such as the Museum are so close in proximity—as this large natural history museum is to Star Elementary School in this research study—the students living in the neighborhood and attending school experience a cultural resource deficit that is ironic, given that visitors from other countries are visiting the same Museum everyday. Students and teachers of students of historically marginalized ethnic groups should be allowed to know of cultural centers and how to access them, especially if they are geographically close to these schools and neighborhoods. Without the knowledge that these resources are available, informal science institutions remain untapped educational centers of cultural and social capital.

As Figure 5.2 reveals, the role of the Museum educator is to assist the classroom teacher to make scientific sense of the objects displayed, scaffold that information, and present it in a way that makes sense to his or her students. By providing teachers with museum-based pedagogical content knowledge, they can "highlight, intensify, and in some cases, defuse the power of museum objects" to focus the student conversation on meaningful dialogue that is able to tell a story (p. 11). When objects "are unpacked and connected, they carry the specifics that are most important to the pedagogical or practical goals of the learning situation" (p. 3).

Additionally, the inclusion of a science coach as a human resource is an undervalued input in any science professional development program. The science coach can act as a conduit to alert students, school staff, administrators, and parents to ISIs. Although few and far between, science coaches, when available, provide a wealth of pedagogical content knowledge that can be shared with teachers, especially elementary school teachers to broaden their minimal experience base to teach science effectively. When activated by teachers, these two resources build their intellectual capital and may reduce or close the achievement gap in urban science education. "The persistence of the achievement gap calls for sustained teacher professional development that will help teachers to implement effective strategies that will enable all students to learn in that culturally complex environment" (Norman, Ault, Bentz, & Meskimen, 2001, p. 1111). Along these lines, the suggestions offered here champion a call for the increased access and activation of cultural resources in urban elementary schools with the assistance of a science coach via the CDLN. As Tate (2001) professes, science education is a civil right. I contend that it should be held accountable by the laws of NCLB and the funding of the American Recovery and Reinvestment Act.

Conclusion

In this study, cultural and social capital were established by a coactiviation of the four characteristics that the four participating elementary teachers exhibited at the end of the Collaborative Diagonal Learning Network (CDLN) PD cycle. The teachers' knowledge of existing museum resources grew as they were introduced to online Educator Guides, free access for public school children, and content-related bulletins about exhibits. The teachers also felt a self-connection to the Museum after taking a personal tour with their friends after the PD. They gained a sense of confidence as they recalled what they learned in their PD sessions to their friends. The teachers became interested in planning museum trips for their classes after their own self-guided tours. After learning how to organize pre-/during/post-trip activities even more efficiently than the professionals who came to their classrooms, the teachers increased their pedagogical content knowledge, PCK in informal science education through the social network that formed from the CDLN.

Chapter VI

LEARNING IN A COLLABORATIVE DIAGONAL LEARNING NETWORK: CASE STUDY OF MARIA

Abstract

This study reports on one teacher's acquisition and use of her increased pedagogical content knowledge (PCK), awareness, and use of resources gained from participation in the Collaborative Diagonal Learning Network (CDLN). Participation in the CDLN model provided her with a science coach and museum-based professional development (PD) in both formal (classroom) and informal (museum) settings. This study uses a qualitative research design and a bounded case study methodology. The participant was a second grade public elementary school teacher in a large urban city. Data were collected via PD sessions, teacher artifacts, classroom observations, researcher's field notes, and interviews. Four main themes are described: increased self-efficacy increased PCK, use of resources, and change in teaching behavior. The study findings have implications for museum trip planning and the positive outcomes of in-service professional development.

Keywords: Professional Development • Elementary Teacher • Self-efficacy • Science Coach • Museum Educator • Teaching Behavior

Introduction

Elementary teachers are not content area experts in science nor do they feel comfortable teaching the subject as a form of daily practice (Mensah, 2010; Moore, 2008b). The pedagogical content knowledge (PCK) of elementary teachers is lacking in any one subject simply because most do not have a single content specialization and are generalists, or common branch teachers, presumably able to execute the teaching of multiple subjects effectively (Appleton, 2006). However, research shows that elementary teachers severely lack the necessary skills to teach science effectively and thus sometimes shy away from it altogether.

Additionally, professional development (PD) programs, when available, are not offered in science, especially for elementary teachers. School districts focus on literacy and mathematics, the two primary areas of state accountability for a school. Therefore, it is essential that the education departments of informal science institutions partner with schools to offer low-cost, high-quality PD to public schools. Due to a low level of PCK, the typical elementary teacher also has a low self-efficacy and is unmotivated to teach science for three reasons: first, pre-service teacher education programs need to focus on the development of self-efficacy (Gunning & Mensah, 2011); second, administrators are not demanding that science be taught because of time constraints and test preparation in the two primary accountability subjects (Spillane, Diamond, Walker, Halverson, & Jita, 2001); and third, teachers simply do not know how to teach science. Hence, an excellent entry to engage teacher learners in science education is an informal setting such as a museum. A natural history museum offers objects, artifacts, dioramas, traveling exhibitions, and print and non-print resources to engage children and pedagogues in scientific and educational discussions (Leinhardt & Crowley, 2001; Shuh, 1999).

Review of Literature

Research shows that elementary school teachers lack content knowledge past a 9^{th} or 10^{th} grade level to execute science effectively in their classrooms (Olson &

Appleton, 2006). Elementary teachers are also at a loss to teach science using the skills they learned in a pre-service teacher education program (Smith & Neale, 1989). When teachers enter the workforce, in-service PD should immediately focus on collegial support through a professional learning community and resource availability. Novice teachers will engage in practices they may not have attempted by themselves with the help of a peer (Appleton & Kindt, 2002). The addition of a coach and informal educator can also greatly influence beginning teachers' confidence level and their acquisition of PCK. For example, the literature has noted the importance of mentoring for beginning science teaching (Anderson & Mitchener, 1994; Gunning, 2010). Interactions between teacher and coach are also vital as novice teachers become developing teachers. Through continuing professional development, developing teachers begin to look beyond their own teaching performance toward a consideration of their students, their own learning, and the general learning experiences being provided by the facilitators (Appleton & Kindt, 2002).

Reformers and researchers argue some major points when referring to in-service staff development. For one, PD should connect teachers to concrete teaching activities and be based on authentic student learning experiences. Without the prospect of learning from and with one's colleagues inside the school in a professional learning community, teacher motivation and activation of resources are low. Finally, PD must focus on deepening a teacher's PCK in science in order to deepen good effectual teaching practices (Ball & Cohen, 1999; Bell & Gilbert, 1994; National Research Council [NRC], 1996; Supovitz & Turner, 2002). The importance of a school-wide infrastructure that supports teacher learning through modeling, coaching, and problem-solving is supported by research conducted by Lieberman and Miller (1981) and Darling-Hammond (1998). PD models where teachers consistently engaged in discussion and discourse around their students and instructional techniques were shown to be valuable.

Accordingly, an organizational culture of support must also exist for PD to be made a priority and a success. As accountability increases with the No Child Left Behind (NCLB) Act and state-/City-mandated annual school quality reviews, PD initiatives encouraging improved teacher and student learning are being viewed more closely for dissemination. As models that employ a collaborative learning environment gain wide support (National Commission on Mathematics and Science Teaching, [NCMST], 2000), the focus of this study was to understand how one teacher was able to construct knowledge through collaboration with formal and informal educators from an informal science institution. Informal science institutions offer teachers the resources and professional assistance that are sometimes needed for those who work in urban schools facing greater challenges with limited availability of materials and inadequate PD (Melber & Cox-Peterson, 2005).

Elementary science reform is sorely needed. Reforms that not only guarantee time for weekly science instruction in elementary school, but also ensure the kind of teaching that will support science learning in the lower grade levels are most desirable. However, in addition to making science a priority for instructional time, teachers need the proper professional development to teach science effectively. Drawing on a socio-constructivist theoretical framework, this paper addresses how a new model for professional development can enhance a teacher's practice. The Collaborative Diagonal Learning Network (CDLN) includes a direct and sustained relationship between an urban elementary school's science coach through in-house workshops, demonstration lessons, and teacher observations with mini-institutes at an informal institution. This PD model was designed to increase teacher self-efficacy for teaching science at the elementary school level. As a means for initiating reform, the model proposes to increase collaboration between experts and teachers while also developing pedagogical practices and teacher self-efficacy.

Self-efficacy, according to Bandura (1997), is developed through four modes of influences: mastery experiences (successful apprenticeships); vicarious experiences (watching similar people succeed at a task through modeling); social persuasion (verbally convincing someone of his or her capabilities); and physiological and emotional states (less stress and a positive mood). Self-efficacy has been applied to educational research where teacher's beliefs and classroom performance have been evaluated (Gibson & Dembo, 1984; Gunning & Mensah, 2011; Ross & Bruce, 2007). As Bandura (1997) states, "Teacher's beliefs in their instructional efficacy partly determine how they structure academic activities in their classrooms and shape students' evaluations of their intellectual capabilities" (p. 240). It is clear that studying the self-efficacy beliefs of teachers' classroom practice is a possible predictor of successful lesson implementation. Pre-service and in-service elementary teachers who are not science specialists have been shown to gain self-efficacy through these aforementioned influences and mentorships (Gunning, 2010; Gunning & Mensah, 2011). Using the theory of self-efficacy, this study examined its development in one teacher over the course of a PD cycle. The study sought to discover which of the four influential forms the teacher uses to build self-efficacy over time.

Methods

Research Design

In this bounded single case study (Merriam, 1998), I focused on the data sources for one teacher that led to and resulted from a teacher's trip to an informal science institution—(Museum). The teacher, Maria (pseudonym chosen by her), taught second grade and had been a teacher for approximately four years at the time of the study. The science curriculum in Maria's school, Star Elementary (pseudonym), follows the City's science scope and sequence. During the four-month period of this study, the second grade class was working on the Full Option Science System (FOSS) Measurement kit and Unit 3: Plant Diversity: How are plants alike and different? (New York City Department of Education, [NYC DOE], 2008).

The data sources for this study included photographs of the Maria's classroom during implementation of science lessons; photographs of students and student work during their trip to the Museum; researcher's notes; two pre-/post-questionnaires rating the effectiveness of the formal (in school) and informal (at the Museum) PD sessions; and audiotaped formal and informal PD sessions. Data were transcribed and used to formulate a case study record which was then analyzed using a grounded theory approach, involving coding for emergent themes and conducting within-case analysis (Strauss & Corbin, 1998). I chose a bounded system to conduct an in-depth study of Maria, who explicitly verbalized a strong need for science assistance. This bounded case study (Merriam, 1998) explored how the CDLN model enhanced Maria's professional learning experience and resource acquisition.

Case Study Participant

Maria is the case study participant. She is a second grade general education teacher who had been teaching at Star Elementary for approximately four years. Maria was one of four other teachers at her school who were all part of a larger study. Maria's journey as a professional learner was extracted from the data analysis because of her extraordinary change from the start of the PD cycle (explained below) to the end of the study. The PD cycle that she participated in was completed within six sessions: formal (three) and informal (three).

The formal PD sessions were conducted at Star Elementary, which is an urban public elementary school. Star Elementary has a PreK-5 student population of 483 students. According to the NYC DOE (2010), the school is ethnically diverse: 45% Hispanic, 25% Black, 21% White, and 4% Asian. At the time of the study, Star Elementary was in the process of building a new science room for their science lab; however, the school did not have a science content specialist to direct and teach the science classes. The Parent-Teacher Association (PTA) is a stellar supporter of the sciences; the president is a scientist herself. The PTA often coordinates (without consultation with the classroom teachers or professional development facilitators) science programs for the students. One particular activity involved the Urban Park Rangers, who provided in-class and in-the-park workshops for the students.

The informal sessions in the PD cycle took place at The Museum, which is a large natural history museum located in the school's neighborhood. In fact, it is one of the largest natural history museums in the world located 12 blocks from Star Elementary. The Education Department at the Museum has "front-line educators" (National Research Council, [NRC], 2009, p. 7). These were professionals (as opposed to volunteers) who use the exhibits and Halls as a teaching tool for learners of all ages, especially public school teachers. Violet and Lillian (both pseudonyms) are two such Museum educators who conducted the informal PD facilitators in this case study. Violet conducted the first session, and Lillian conducted the last two sessions. Even though the Museum is within walking distance of Star Elementary, the school has not taken advantage of the Museum for PD or field trips to enhance the city-adopted science curriculum or to support science as an out-of-classroom resource.

As the coach working closely with Maria, I conducted our formal PD sessions using a traditional cognitive coaching model (Reed, 2006). I also collaborated with the Museum, as well as the principal and staff at Star Elementary, to plan and provide a coordinated PD model that included collaboration and classroom support for relatively novice yet experienced staff. As the science coach, I was responsible for providing feedback, modeling, training teachers, and coordinating resources between the three components of the Collaborative Diagonal Learning Network (CDLN) model, as shown in Figure 6.1.

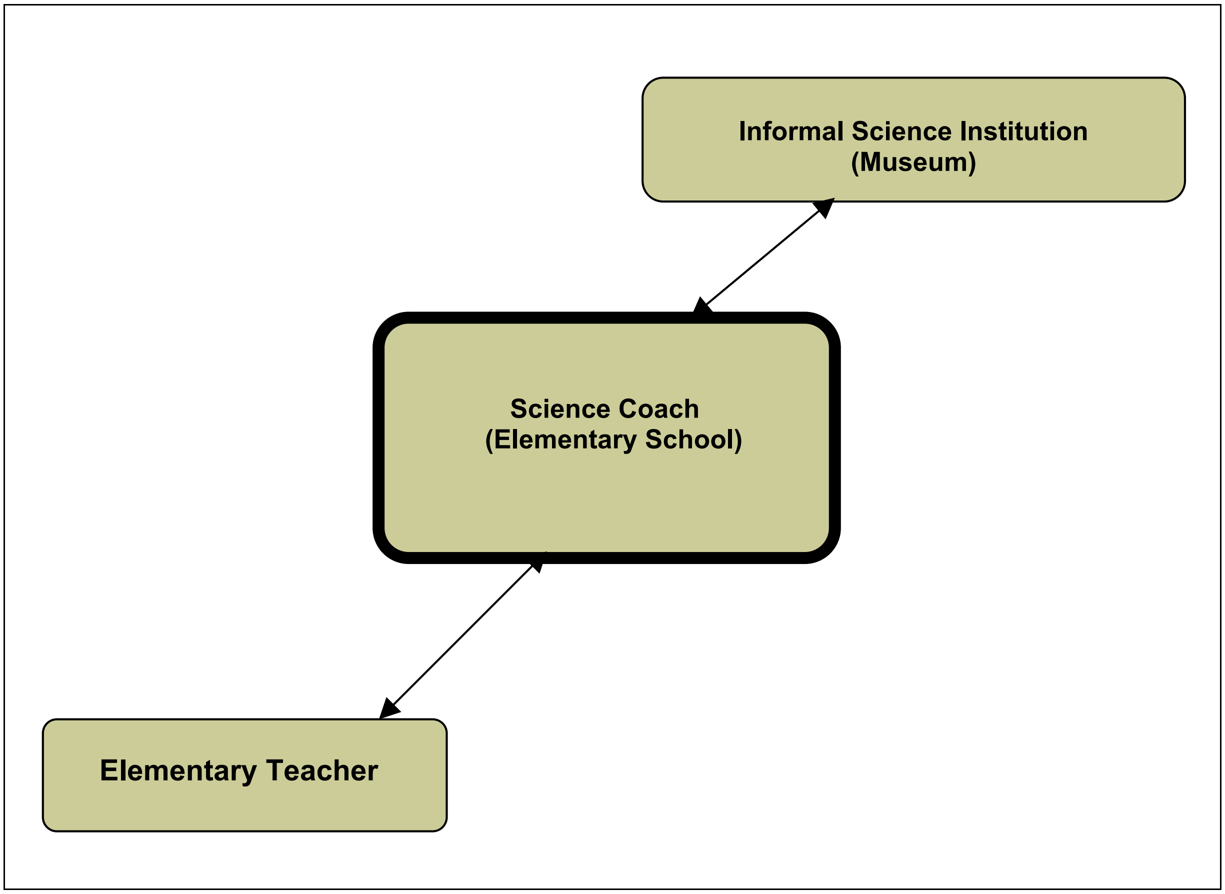


Figure 6.1. Collaborative Diagonal Learning Network (CDLN)—Theoretical Model for Interrelationship with Formal and Informal PD Providers.

The Collaborative Diagonal Learning Network Model: The PD Cycle

The professional development cycle of the CDLN consisted of three 2½-hour informal PD sessions led by Museum educators and the science coach held at the Museum, and three 45-minute formal PD sessions led by the science coach held at the Museum and Star Elementary, from March to June 2010. The Museum educators led most of the informal sessions and the science coach debriefed for the last 30 minutes of each session. The informal and formal PD facilitators served two roles. The main role of the Museum educator was to be an agent of resource knowledge. Using Museum trip online educator information and related science education articles, Violet and Lillian educated participants with content knowledge (i.e., basic scientific facts about artifacts and collections); provided uninhibited access (i.e., 2 sets of free special exhibit admission tickets at the first and last sessions); and demonstrated inquiry-based knowledge, such as questioning techniques through science notebooking, observation skill-building strategies, to the teachers about the objects, dioramas, and exhibit halls. The main role of the science coach was to be an agent of classroom support. I as the coach followed up the sessions given by the Museum educators by providing curricular knowledge about the Museum exhibit and how it connected to the current unit of study, and supplied pedagogical knowledge on how to integrate a museum trip experience into the classroom. I also gave Maria science education articles and demo lessons, and conducted in-class science lesson assistance.

Data Collection and Analysis

Several data sources were used to construct Maria's case study. First, all of the PD sessions were audiotaped to capture learning from the informal and formal PD sessions. Maria completed open-ended pre-/post-questionnaires to assess the effectiveness of the PD sessions and whether or not she used the resources from the session. Maria participated in audiotaped semi-structured group teacher interviews as well as a semi-structured individual teacher interview to gauge her PD needs. As part of the formal PD sessions, I observed Maria in her classroom teaching science lessons and collected artifacts of her teaching (e.g., photos to document the classroom-based and

Museum teacher-made artifacts). Finally, I kept researcher field notes as an observer and a participant on field trips to the Museum with Maria and her class.

The data sources were transcribed and analyzed using the constant comparative method to determine common codes, categories, and themes over time (Creswell, 2007). In this study, different types of data collection (interviews, observations, artifacts) that occurred within different settings (PD sessions, interview setting, lesson observations, and Museum trip observations) were triangulated to increase rigor and validity (Creswell, 2007; Guba & Lincoln, 1981). For example, during the process of analysis, particular examples of descriptive codes early in the analysis emerged as *self-efficacy* (feelings of confidence and ability to teach science with minor questions) and some general codes for *PCK development* (new lesson planning and sharing, teacher questioning and answering, revision of museum worksheets, and inquiry-based activities). Early codes for the theme of the use of resources provided during the study were Museum trip planning, using and revising Museum worksheets, and making use of "free" tickets to visit the Museum. Finally, based on observations of Maria's class, coding examples for a change in teaching behavior were increases or decreases in the volume of her voice when she addressed her students.

Findings

The results are presented as a change over time documenting Maria's increase in self-efficacy, increase in PCK, use of Museum resources, and changes in teaching behavior. Specific examples or vignettes from the data sources (mainly verbatim transcribed PD and interview sessions as well as researcher's field notes) are offered as key occurrences in Maria's pattern of teacher development and evidence of change over the course of four months of participating in the formal and informal PD sessions. Her knowledge acquisition of using information from the PD sessions and making connections between the Museum and her classroom revealed four major changes or themes before (pre) and after (post) the CDLN cycle of professional development, as delineated in the next sections.

Increased Self-Efficacy (Pre and Post CDLN)

First, there was a change in self-efficacy:

Observed Theme	Sample Response (pre)	Sample Response (post)
Increased Self-Efficacy	"I thought I knew what I was doing in FOSS but apparently not." (Maria, quote-Researcher Field Notes, 5/11/10)	"When you came in, it was very helpful because I got to see a lesson." (Maria, Formal Post Questionnaire)

Maria never received PD on how to use the FOSS kit for the science curriculum. Prior to our work together, Maria stated that she simply skimmed the directions and attempted to teach the lessons with little direction or guidance on how to execute the inquiry-based investigations. Maria learned through her colleague, Venus, that sometimes videos accompanied the teacher's guide. During the first formal PD session, she admitted that she had messed up one of the lessons on balancing:

> I actually looked at the first investigation and I pulled out all the materials for that investigation and so I have it there prepared and I also looked at the little video which I love the little video and apparently you should watch the little video because we did the crayfish and they had to balance it on their nose. And then I watched the video for the upcoming/the lesson following lesson because I didn't get a chance before. So, I said let me

> look at the other one and let me see if I did it right. They're supposed to balance it on the crayfish's nose! I was like ohhh. So, I think I have to view the videos not just read the stuff…but view the videos beforehand to help me understand. (Maria, Formal PD Session #1)

Maria later mentioned that she had taken some pictures of the entire experience and posted them proudly on the bulletin board along with her students' work, only to find out that the investigation was done wrong. Maria's self-confidence prior to and after the lesson was not very high. She asked for assistance in her classroom the following week.

By engaging in the formal and informal PD, Maria showed a change in self-efficacy. For example, Maria was able to engage in new teaching practices in her classroom after seeing me model a science activity; she noted, "When you came in, it was very helpful because I got to see a lesson" (Maria, Formal Post-PD Questionnaire). However, most evident of her confidence in teaching science was the trip to the Museum that she had planned for her class. She was given advice and mentorship from the science coach and Museum educators to plan for an appropriate and engaging museum learning experience for her students. While at the Museum with her students, Maria was able to differentiate the existing Educator Guide activity and create a worksheet with a chart to make recording her second graders' observations more manageable. For instance, 21 organisms were found in the Hall of Biodiversity. To make this more appropriate for her students, Maria told her students to choose five organisms and respond to three focused questions: Where in the forest do the organisms live, how do the organisms move, and what do the organisms eat? (see Figure 6.1).

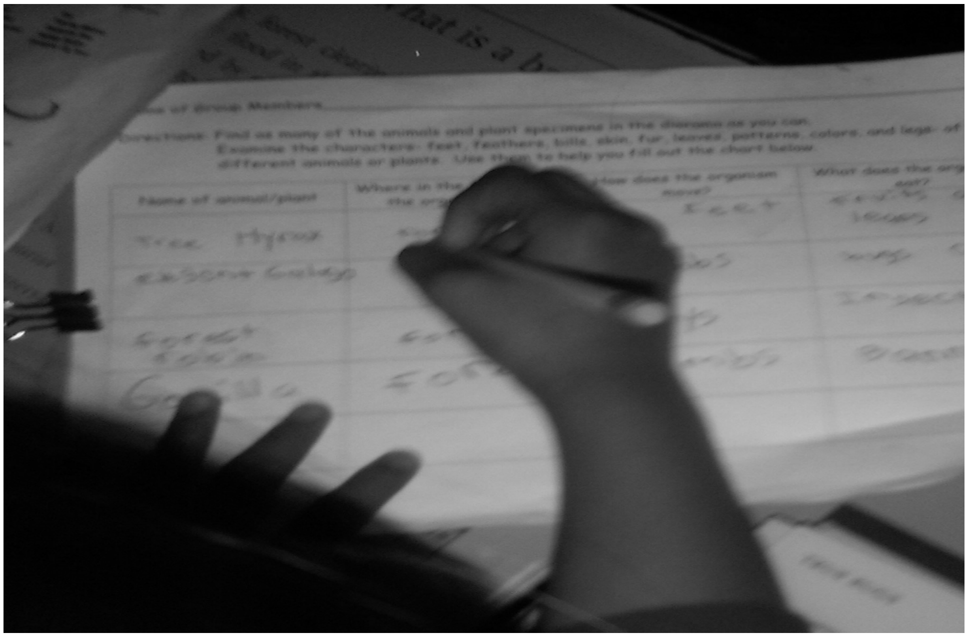


Figure 6.2. Maria's Class Museum Trip: Event Documentation—
Student Worksheets (6/18/10)

<u>Increased PCK (Pre and Post CDLN)</u>

Second, there was a change in pedagogical content knowledge:

Observed Theme	Sample Response (pre)	Sample Response (post)
Increased PCK	Did demo lesson today with Maria's class on dissecting a flower. Gave class a chart to copy in their science notebooks (promoting use of notebooking) with the amount of petals, leaves, anthers, pistils, and stamens they found (Researcher Field Notes, 5/18/10)	"The way you organized the chart for children to track their learning was great. I used it when we were keeping track of the info for their field guides." (Maria, Formal Post-PD Questionnaire)

Another example of increased PCK can be seen from an observation on May 11th, where Maria presented a very teacher-directed lesson with multiple instances of her yelling at her students to follow the directions. She appeared annoyed that the students did not have sharpened pencils. She appeared agitated with the task that the students were given: they were researching information to complete their field guides. The task lacked definite structure and guidance, which explained both her agitation and the students' disarray (Researcher Field Notes, 5/11/10). Overall, Maria was frustrated with her students' inability to complete the learning objectives she had planned for the science lesson.

In our one-on-one interview the following week (May 18th), Maria explained how she was surprised by the student organization and completion of the flower dissection activity that I was doing with her class. When planning the lesson, I wanted to make sure that I showed Maria how to organize a science lesson so that her second grade students could follow along and keep track of their ideas. I also wanted the students to use their science notebooks and add some authentic individual student data besides rote note-taking and whole class observations.

Maria in fact incorporated what she had observed from the in-school demo lesson and the co-teaching experience I had done with her students. For example, in a demo lesson on flower dissection, I used a data collection table as a way to visually organize the students' observations. The number of each flower part was identified and counted. Maria thought the data tables were "great" for helping students to organize their ideas. Still working on the nature field guides lesson a month later, Maria created a similar table to assist students in organizing their ideas (see Figures 6.2 and 6.3). Using strategies to increase student understanding was useful in developing Maria's PCK.

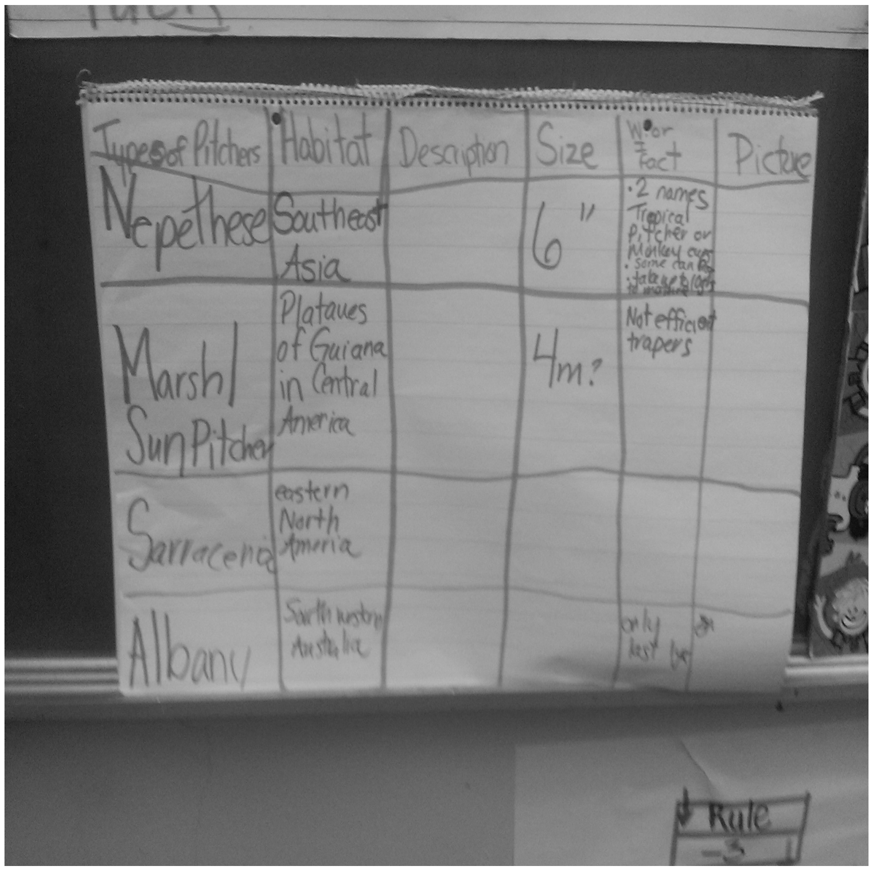


Figure 6.3. Maria's Classroom: Teacher-made Chart Drawn as Template for Students to Make Their Own Field Guide Page (6/3/10)

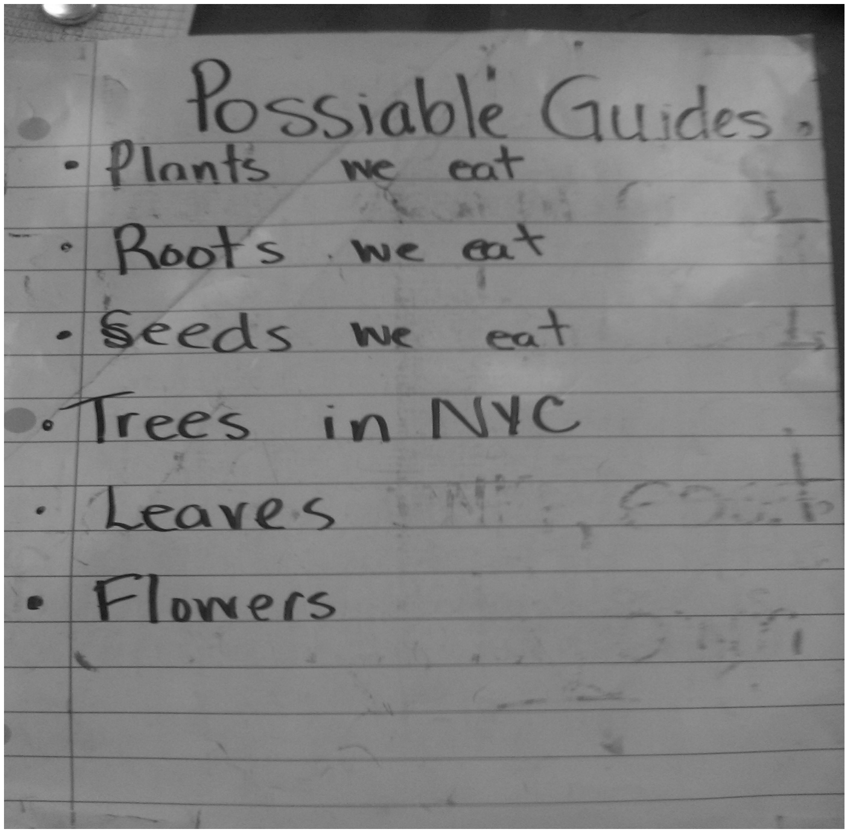


Figure 6.4. Maria's Classroom: Teacher-made List with Student Field Guide Title Ideas (6/3/10)

Use of Resources (Pre and Post CDLN)

Third, there was a change in the use of resources-both material and cultural before and after the CDLN PD cycle of teacher support:

Observed Theme	Sample Response (pre)	Sample Response (post)
Use of Resources	"I would like to attend science PDs to help my teaching but have not been aware of any." (Maria, Formal Pre-PD Questionnaire)	Maria enrolled in *Science in the City* course at nearby college that incorporates informal learning at The Museum into curriculum and offers free membership for one year .(email correspondence with instructor of the course)
	"I wouldn't have at all [referring to coming to the Museum]. I don't think I've [referring to bringing her students] ever been to the Museum." (Maria, Formal PD Session #3)	Maria scheduled a trip on her own to the Hall of Biodiversity with her 2^{nd} grade class. (Researcher Field Notes, 6/18/10)
	"I personally would like to see more what they [the Museum] have to offer, like I've seen some of it and I think it's great but…but for my kids it might be a little bit too…. It doesn't go so much with my science program or I can't envision it." (Maria, Formal PD Session #1)	"Yes, because it [PD] opened my eyes to resources that I didn't know about." (Maria, Formal Post-PD Questionnaire)

Maria had not been offered science PD by her administration because the focus for the city schools, and for her school as well, was literacy and mathematics. At the beginning of the study, Maria let me know that she was interested in attending science PD and needed assistance with the FOSS kit program. Prior to participating in the PD sessions, Maria had not attended the Museum, nor had she taken her students to visit it as a school trip. She felt that it was “too much” for her students to attend and learn from the Museum. Even though she felt this way, Maria was encouraged and eager to be shown how to bring her class to the Museum and to see what the Education Department had to offer her in terms of her own edification.

Because the informal PD sessions were on-site and accessible to Maria, she became comfortable with the Museum. For example, she was given two personal passes to visit the Museum, which she used by taking some friends. Participating in the PD sessions at the Museum also allowed her to get acquainted with the Museum and what it had to offer. She was shown how to make learning in the Museum enjoyable to her students. Therefore, Maria scheduled a class trip on her own without any assistance. She planned a Museum trip to attend the Hall of Biodiversity with her second grade class. She also encouraged another second grade teacher/class not involved in the original study to accompany her students, hence building capacity within Star Elementary.

Maria was also enrolled in a *Math in the City* course at a local university but was unaware until I informed the group that there was a science version of that course offered at the same college. After Maria completed her *Math in the* City course, I found out from one of the instructors of the *Science in the City* course that Maria had enrolled in it. The graduate-level course incorporated informal learning at the Museum into the existing City science curriculum and offered free membership for one year (email correspondence with co-instructor J.B.).

Change in Teaching Behavior (Pre and Post CDLN)

Finally, there was a change in teaching behavior:

Observed Theme	Sample Response (pre)	Sample Response (post)
Change in Teaching Behavior	Maria is a little disorganized with her lesson. She is yelling at three children who don't have pencils and yelling at the entire class because they are taking too long to copy a chart from the board inside a field guide booklet she made with 3 pieces of paper. I applaud her effort for using a graphic organizer but suggest to her to have less info in the chart and that it would have been easier just to photocopy the chart instead of the kids wasting time trying to copy it. (Researcher Field Notes, 6/3/10, also see Figure 6.1)	Maria used the Educator Guide Violet and I showed her during the first PD. She actually explained that she created a worksheet to meet the needs of her 8-year-olds. She made it easier and wrote out the animals they are supposed to find today. She is more calm and laid back as the kids are off exploring on their own and showing me that they're putting their answers in the chart. (Researcher Field Notes, 6/18/10, also see Figure 6.1)

Maria's change in teaching behavior was noted as changes in her conversational volume when giving activity directions and instructing students to complete or write down notes on their worksheets. Early in the study and from watching her in the classroom, Maria was often agitated and frustrated by teaching science. She has a particularly strong voice and would yell at the students to do the assigned task in the classroom. Additionally, Maria would rarely scaffold her science lesson content or independent activity. This caused the students not to understand what to do or what the purpose of the activity actually was (Researcher Field Notes, 6/3/10).

As the study progressed toward the end of the PD cycle, Maria's teaching behavior during instruction noticeably changed. Her conversational volume when assigning tasks for her students was reduced. It seemed that after the trip to the Museum, Maria had developed a softer tone with her students. She was more organized in her teaching approach to meet the needs of her students. For example, Maria received a lot of support and advice from the science coach. For example, to prepare for the June 18th trip to the Museum, I suggested a pre-/during/post-trip mini-unit plan. As part of the during-trip activity, Maria modified the Educator Guide resource to construct a museum trip worksheet suitable for the second grade science curriculum. Maria not only transformed her teaching practice in a short amount of time (4 months), but in doing so, she also changed her teaching behavior and approach to teaching science. By becoming more organized and purposeful in her planning, and thus more confident (increased in self-efficacy), she was able to alter her management style, which resulted in reducing her anxiety (and her students) on the out-of-class outing.

Discussion and Implications

This study reports the findings of one teacher participant's learning by her participation in the Collaborative Diagonal Learning Network (CDLN). She increased self-efficacy in teaching science which was manifested in other ways, such as an increase in PCK, her use of new museum resources, and changes in her teaching behavior. In particular, Maria developed an increased self-efficacy and PCK in planning and teaching a unit as part of the City's required scope and sequence. She also became aware of resources that the Museum offered and used them to coordinate a museum trip for her second graders. She took the initiative to plan without involving others. Throughout the four-month PD cycle, but most evident toward the end of the cycle, there was a noticeable change in teaching behavior that emerged as Maria became more organized in her instructional delivery. With guidance and support, Maria's expertise to plan and implement science was strengthened because of the networking factor of the CDLN that brought together peers, museum educators, and a science coach as a form of science teacher professional development. Thus, the argument set forth in this study is the importance of professional development to assist teachers in building self-efficacy. This was accomplished by Maria's participation in the CDLN professional development model—the diagonal relationship of an informal science institution, a formal school setting, and a science coach who brings these two entities together. As a unified collaboration, all three provide vicarious learning experiences through modeling and resource use to build teacher self-efficacy (Bandura, 1997).

The findings of this study suggest that an increase in self-efficacy allows teachers (Maria in this case) to build stronger ties to science and to develop a belief in their ability to teach science. Maria believed she was successful in teaching science in and out of the classroom, and was able to connect science across these two settings. She acted on a particular belief (Bandura, 1997): that she can be successful in teaching science and making connections for herself and her students. Research shows "personal teaching efficacy as the best predictor of teacher behavior" (Dembo & Gibson, 1985, p. 175). A teacher's belief in his or her ability to do (i.e., teach science) plays a significant role in what the teacher can accomplish through independent and group activities chosen for science instruction.

Furthermore, the teacher's perceived level of self-competency affects classroom management styles and the effectiveness of lesson presentation (Bandura, 1997). In this case, Maria became confident in her own science teaching ability and realized that, upon the advice of two sets of experts, organization is the key to a sound mind and an attentive well-behaved class. Fewer student disruptions occur when activity directions are introduced because they are clearly written in the trip mini-unit. Overcoming obstacles to accomplish the learning goal provides a lasting sense of ability for the teacher to do well in the lesson. Maria's feelings of stress and anxiety were lessened when she relied on her emotional state to build her personal self-efficacy (Bandura, 1997). This asserted a positive influence in her ability to effectively deliver a lesson and conduct a field trip.

Maria effectively scaffolded her students' readiness level to conduct a student-driven activity and engage them in a self-mediating task to learn about organisms in a rainforest (Rivera Maulucci & Brotman, 2010). However, Maria allowed her students ownership of their experience based on the guidance of the Museum educators and the coach. She created an observation worksheet as a museum trip resource according to the needs of her second grade class. As related to the contextual model of learning (Falk &

Dierking, 2000), the task Maria assigned to her class in the Hall of Biodiversity could be categorized as a concept agenda, whereby her worksheet had a specific goal and a particular concept to be clarified while at the Museum (Kisiel, 2003). The worksheet was designed with the characteristics of task density (fewer questions, more time to explore), information source (responses based on objects), and level of choice (student choice of object to be studied) (Kisiel, 2003). Maria also extended freedom to her class and made the Museum trip data-gathering activity for her students more motivational; she allowed them more freedom to roam the exhibit space and learn on their own. The children developed a sense of academic capital as they became the leaders and directors of their own engaging learning experience (Spillane, Diamond, Walker, Halverson, & Jita, 2001).

Teachers in Kisiel's (2006) study, as well as Maria in this current study, used multiple strategies, including following a trip action plan (supervision), having a science coach/museum facilitator (student engagement), permitting grouping and parent chaperoning (supervision), and taking photographs (Figures 6.1-6.3). Maria had more unstructured student engagement strategies which included interpreting an exhibit (based on her own learning experience at the Museum, how animals are displayed in the cases); connecting concepts to the classroom curriculum (showing a connection to the animal scavenger hunt activity at the museum to the plant field guides they made in class); facilitating student thinking; reading labels (pointing out animal field guides at the base of the Rainforest exhibit); and allowing free exploration (children using computer touch-screens by wall of the "Spectrum of Life," and an unplanned docent talk by portable cart). To a lesser degree, Maria also used structured student engagement strategies that focused on information-seeking (Rainforest exhibit scavenger hunt) or information receiving (science coach pointing out the hidden gorilla in the diorama).

Therefore, the findings of this study revealed that Maria exhibited a higher degree of PCK and self-efficacy to teach and use the Museum, compared to the beginning of the study. With Maria's increase in confidence level, she adapted her field guide lesson and designed a chart modeled after one from a demo lesson given by the science coach a month earlier. Using non-fiction texts about various flower species that the students read previously, Maria arranged this information for easy access on a table. She provided a graphic organizer for the children to group flowers. By doing all of this, Maria was able to assist with meaning-making and organize their students' prior knowledge (Kisiel, 2006). Thus, Maria's learning from CDLN relationships was significant. She developed self-efficacy and PCK in teaching science using the Museum as a resource.

In summary, as Rivera Maulucci and Brotman (2010) note, teacher support in informal science institutions and in schools should include assisting elementary teachers to (a) build a classroom culture that fosters student engagement and learning in free-choice settings; (b) identify their stimulus for taking class field trips at different points in the school year; and (c) bring in approaches teachers already utilize and open their eyes to new innovative approaches they have never tried before. This was clearly the case for Maria.

Conclusion

As a learner in the informal setting of a museum and receiving additional formal support in her classroom, Maria was able to think about herself as someone who knows about and uses science (NRC, 2009) and has access to science. Maria went from being teacher-centered in a formal classroom environment to becoming more student-centered in an informal museum environment. Her increase in self-efficacy in this study shows, as Hein (2006) recognizes, that teachers who participate in informal institutions are able to welcome the idea that they too are part of the museum education community. Through exchanges with museum educators and free access to the Museum, Maria became linked with the informal science institution and its resources. As a member of the Collaborative Diagonal Learning Network, she took advantage of opportunities to learn from museum educators, the science coach who was linked to both the school and the Museum, and then to share her knowledge and experience with her students. Maria's ownership of the theoretical framework behind each component of the CDLN led her to grow and develop as a science teacher. Elementary teachers require professional support and guidance to recognize what and how to use science resources that are available to them—in museums as well as in coaching models in schools. When they are able to take advantage of PD and resources for teaching science, their self-efficacy increases along with their PCK and many additional benefits can be discovered in their teaching.

Chapter VII

CONCLUSION AND DISCUSSION

The purpose of this study was to examine how formal and informal professional development (PD) shapes the acquisition and use of cultural resources and teachers' pedagogical content knowledge (PCK) through a Collaborative Diagonal Learning Network (CDLN). An in-depth qualitative look at the model under investigation used a grounded theory methodology. Specifically, this study explored the intersection of teacher learning in the context of informal and formal settings, embedded with classroom support from a science coach and museum educators.

Summary of Major Findings

The findings of the dissertation were written as three independent papers. First, Chapter IV provided a cross-case analysis of four elementary school teachers through an examination of their PCK acquisition using the CDLN model of professional development. This study revealed that the teachers did indeed increase their science PCK and knowledge of museum education. Unexpected outcomes included increased self-efficacy due to critical though positive feedback from the science coach and museum educators and from their teacher-teacher collaboration. During pre-/post-observation conferences and interviews, the science coach met with the teachers and not only gave them areas of improvement but also accolades for increasing their level of science teaching effectiveness by the conclusion of the four-month PD cycle. One of the main findings, acquisition of science PCK, was evident in numerous teaching behaviors and activities implemented in class or on museum trips in which the teachers participated and also visited with their students. Among these behaviors and activities were the use of student science notebooks, instructional differentiation (i.e., revised museum trip worksheets), and strategies to prepare for the grade four state science exam.

Second, Chapter V examined the acquisition of teachers' awareness and practical use of informal science institutions using the CDLN model. One primary category that emerged from this data analysis was the increased knowledge of museum resources. Secondary categories were a self-connection to the museum, PCK in museum education, and planning a class museum trip. Although the teachers knew about the Museum as a cultural resource in the City, using the Museum as a visitor and for their students was dependent upon their activation and transformation of the Museum as both cultural and social capital. Without the use of what the Museum offered them and their students, the knowledge of it as a cultural resource for science learning remained a piece of stagnant information, with no effect on changing the mindset of how teachers plan and use informal resources for their professional growth and student learning.

Finally, Chapter VI gave an in-depth look at one teacher, Maria, who stood out during data analysis. Using a bounded case study methodology, four themes emerged: an increase in self-efficacy, an increase in PCK, use of resources, and changes in teaching behavior. These findings were similar to previous themes explored in earlier chapters yet the case study methodology allowed me to look more intently at one teacher's learning from the PD model proposed in this study. Evidence showed that with a strengthened sense of self-efficacy and PCK with science teaching, Maria was able to engage in new teaching practices with the advice and mentorship of the science coach and the museum educators. As an example of this complementary association between self-efficacy and PCK, Maria created a concept agenda-based worksheet by modifying an Educator Guide in preparation for the museum trip activity she planed for her second graders. Moreover, during one lesson, she introduced a graphic organizer that she had observed the science coach use during a demo lesson. Maria's demeanor also changed while on the museum trip: she became calmer due to her organization and pre-planning of the museum visit. Thus, her implementation of learning from CDLN relationships was more significant than it was for the other three teacher participants, particularly in her ability to develop self-efficacy and PCK in teaching science using the Museum as a resource.

Synthesizing Findings across Chapters

Four recurring themes presented themselves in the findings of each study: an increase in pedagogical content knowledge (PCK); the use of educational resources, an increase in self-efficacy, and the learning of teachers by participating in a collaborative professional development PD community. In this section, I make reference to the original purpose and origin of this study in addition to providing an evaluation of the CDLN model.

Although science education literature has a great deal of published material evaluating PD programs in and out of school settings, with and without outside organizations, businesses, and informal science centers, this study is distinctive in its systematic examination of three normally separate entities working in partnership as cooperating links and coactivating resources (Rivera Maulucci, 2010). On the whole, inadequate research has been conducted on PD in formal and informal settings. In addition, information regarding the impact of PD on the teacher effectiveness of elementary teachers in science is very limited (Michele, 1998; Rivera Maulucci & Brotman, 2010). Generally, elementary school teachers continue to receive professional development from a top-down approach (i.e., vertical learning, Van der Krogt, 1998).

The Collaborative Diagonal Learning Network (CDLN) model was developed as a theoretical approach to bridge two normally individual and distinct forms of formal teacher professional development by adding a third, new, and underutilized dimension—informal staff expertise—in the design of a teacher professional development model. The theoretical representation of the formal and informal professional development model for elementary school teacher participants was constructed based on an earlier pilot study (Cooke & Moore Mensah, 2009). The purpose of that study relied essentially on the participant's dislike of teaching science but love for the nature of science (being that the teacher was a graduate of a specialized high school for science) and his affection for animals. In accordance with that view, we were less concerned with the acquisition of content knowledge and resource allocation because he was already well-versed in science and knew where to find resources. However, in that study, the teacher did not teach science at all to his fourth grade class, which had serious implications in that his students were to take the state science exam at the end of the year. The results of the pilot showed an increase in the amount of science teaching—from zero to approximately twice a week.

Though grounded in the overarching findings of the pilot, the Collaborative Diagonal Learning Network is intended to serve as a professional development program for the professional development of elementary teachers. Elementary teachers are the target group, considering their general lack of content knowledge, PCK, and resources to teach science (Bryan & Abell, 1999; Koch & Appleton, 2007; Loughran, Mulhall, & Berry, 2004; Smith & Neale, 1989). Further, elementary teachers generally have no science specialization (NSTA, 2003). The CDLN set to establish in the current research study that "the strongest programs result from collaborations among teachers, developers (such as science coordinators), and other stakeholders (such as scientists, science-rich centers, and community organizations)" (NRC, 1996, p. 71). The CDLN program model also intends to open the doors for future research on science coaching, a practically nonexistent topic within education research articles.

The Collaborative Diagonal Learning Network presents a good and sound theoretical model, one that holds under different conditions and multiple perspectives (Creswell, 2007). For example, the overall consequences of this model are varied and detailed and have intertwining resultant threads that span each study, thus providing future researchers with the ability to replicate the methodology. The transferability for researchers of the CDLN theoretical model takes place as one examines the results in the context of other informal science institutions. Typical in qualitative research, the results of these studies are unique to the particular investigator, study participants, and context (Creswell, 2007). However, data analysis showed in both the pilot study and the research findings here that elementary teachers can increase their PCK, resource knowledge, and use, as well as change their belief system about themselves and science education (Figure 7.1). In view of these findings, there is a strong case for the consistency and dependability of the CDLN as a sound model for professional development in urban elementary schools, and not just for elementary school teachers, though this is a well-deserved area to highlight.

One of the overall goals of this study was to evaluate the transferability of the piloted CDLN in order to provide future stakeholders and researchers with the ability to implement and replicate this model. As Killion (2003) states, “Staff development is most successful in increasing student achievement when it targets changes in knowledge, attitude, skill, aspiration, and behavior” (p. 19). Killion’s logic model provides a framework for conducting a qualitative evaluation of the professional development process undertaken in this study well as of the overall research design.

Specifically, the logic model lists the interim benchmarks of progress from short-term to medium-term to the observed long-term goal (see Table 7.1). The logic model identifies changes as a result of adding each PD cycle. Table 7.1 shows a dynamic model illustrating its structural features (inputs), PD activities, social features (initial and intermediate learning outcomes), and documented CDLN model outcomes (outputs).

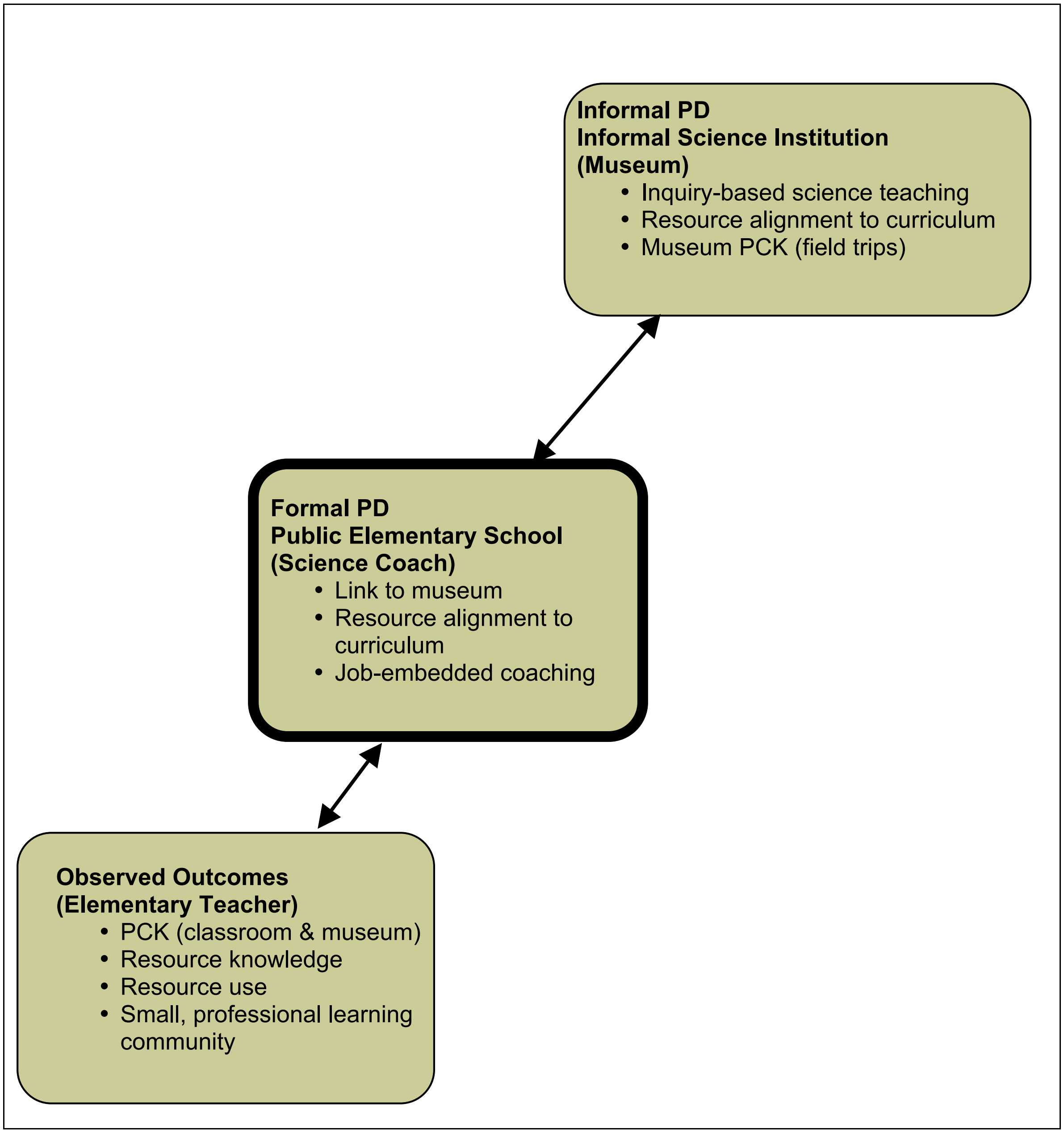


Figure 7.1. CDLN Model with Characteristics of the Diagonal Linkage

Table 7.1. *Logic Model for Collaborative Diagonal Learning Network*

CDLN Model (Inputs)	**Activities**	**Initial Learning**	**Intermediate Learning**	**CDLN Model (Outputs)**
Science Coach	Science Coach conducts three Formal PD sessions, demo lessons, co-teaches; conferences with teachers	Knowledge and Skill-Teachers develop increased pedagogical knowledge, pedagogical science content knowledge through expert mentor	Behavior-Teachers incorporate science coach suggestions into lesson planning. Behavior and Aspiration-Teachers respect critical feedback from coach and gain confidence in teaching science.	Elementary teachers acquire PCK and enhance their awareness and practical use of Informal Science centers by the end of the CDLN cycle.
Museum Educator	Museum educators conduct three Informal PD sessions; teachers tour temporary and permanent exhibits and halls in museum	Knowledge and Skill- Teachers increase pedagogical science content knowledge through expert mentor Knowledge- Teachers learn about museum trip strategies and resources	Attitude-Teachers feel welcomed in Museum. Behavior and Aspiration- Teachers integrate resources and materials into their lessons (e.g., observation sheets and science notebooking)	
Time to Collaborate with Science Coach and Colleagues	Collegial coaching model (semi-structured sessions with coach, pre/post observation conferences, formal PD sessions)	Knowledge- instructional sessions with science coach about curricula and museum resources	Behavior-Teachers across grade levels share best teaching strategies in science	
Free Access to Museum	Science coach and Museum Educator give out tickets to teachers at first and last PD sessions	Behavior-Teachers visit the museum with their family and friends within first two weeks of PD	Attitude, Aspiration, and Behavior-Teachers feel confident to plan and take class on museum trip	

Adapted from Killion, 2003

With multiple variables and feedback loops, assessing the impact of the CDLN as a formal-informal diagonal collaboration is much more suitable and trustworthy than the historical linear model of professional development (Bevan et al., 2010). It is the diagonal relationship of bringing together separate entities under the same umbrella.

Limitations

As mentioned earlier, one limitation of this study was the amount of time the study required. Time is a commodity that is sorely needed in all professional development programs. Long-term study requires a certain degree of commitment and funding on a larger scale such as a creative way to schedule time for PD during the instructional day; thus, activating time as a strategic school resource must be taken into consideration for this model of professional development (Rivera Maulucci, 2010). Dori and Herscovitz (2005) conclude that long-term professional development over a period of three years was necessary for teachers to move from basic exposure to new teaching practices and science subject matter into sustained science PCK inherent in a teacher's classroom culture. Since three years is a suggested timeframe to see impacts of sustained professional development, it is unfortunately not practical. With constrained financial resources (i.e., grant/financial resources) and commitment on the part of school districts, administration, and teachers, professional development models such as the one proposed here will have to be truncated. However, one suggestion for future implementers of the CDLN is to extend the four-month timeline completed in this study to six months or even one academic school year, if possible. Time to complete one cycle of PD in both formal and informal settings is ideal; still, additional teacher-directed activities that show the impact on student learning may be recognized with more time for the teachers to prepare and reflect on their learning and to use informal institutions to enhance the teaching and learning of science.

Implications and Future Directions

The findings of this dissertation answer the call for an addition to the literature in the field of museum-school partnerships, specifically in urban elementary schools. In order to further the research agenda within science education, suggested directions in professional learning, PD in informal settings, and PD in formal settings are given in this section. This then addresses issues of reform-minded teacher professional development models and approaches which are critical to the goals of science education as it expands to incorporate science in elementary education.

Implications for Reform in Professional Learning

The findings of this study show potential contributions to pedagogical practice in elementary school classrooms. As a new call for teacher education reform sounds in the 21st century, urban city school districts who are searching for highly-qualified teachers in the last decade are now giving tenure to those who are highly effective teachers.

The National Staff Development Council (NSDC) (Wei, Darling-Hammond, & Adamson, 2010) released a report which highlights the need to develop local experts who can support job-embedded professional learning. In addition, they encourage policymakers to evaluate the effectiveness of PD programs by not solely concentrating on student achievement, but by extending the focus to teachers' learning, reaction, use of new knowledge and resources, and the mechanisms that are in place to support teachers over time. As Wei, Darling-Hammond, and Adamson (2010) state, for professional development to have long-term effects, teachers need at least 100 hours in mathematics and science professional development, as well as continual support from all educational parties: "professional learning should tap the expertise of educators in the school and at the district office, with support from universities and other external experts who help local educators address needs specific to their students and school improvement goals" (p. 3). Putting the CDLN model into practice requires the support of informal resources and a district or in-house science coach.

A science coach as a source of professional development in the CDLN model improves teacher practice in science. The mere mention or use of the term "science coach" in the literature is nearly absent. Tobin and Espinet (1989) state two coaching models; neither includes an in-house staff member whose sole responsibility is to mentor teachers. The researchers identified two grade-level teachers as one model and three university science educators as the second model. The CDLN model suggests the need to hire a science coach in elementary schools. As shown with Maria's case study (Chapter VI), her major impediment to change were her beliefs about teaching and learning science and her relatively poor knowledge of the science content she was expected to teach. The science coach and the museum educator allowed Maria's belief system to be altered (through modeling, co-teaching, advising), thus allowing her the opportunity to add more structure to her lessons. Maria also developed confidence (self-efficacy) to plan a museum trip for her students, something that prior to the CDLN was not an option. As a result, Maria's confidence was higher when she felt capable of explaining the exhibits to her students at the Museum. Thus, the presence of a science coach enables teachers to make instructional improvements and to transform their teaching strategies to be compatible with their new teaching style (Glickman, Gordon, & Ross-Gordon, 2007). These changes complement reform-based notions of science teaching (NRC, 1996).

Implications for Reform of PD in Informal and Formal Settings

This study addressed the literature gap and focused research in science and informal education on the growing interest and reform of museum education towards new types of school-museum partnerships and professional development programs for teachers (American Association of Museums, 1982, 1992). Results from this dissertation suggest that informal settings can offer valuable and enriching opportunities for teachers of science to engage in learning experiences not found in typical formal settings, such as school-based workshops. Typically, formal settings offer "classroom context, structured, non-curriculum based, solitary work, teacher-centered, close-ended environments"; by contrast, informal settings offer "out-of-school context, curriculum based, unstructured, social intercourse, learner-centered, open-ended" environments (Hofstein & Rosenfeld, 1996, p. 89). The findings from this study indicate that informal and formal PD sessions can have characteristics of both and be equally effective in increasing teacher self-efficacy and PCK.

In the informal PDs at the Museum, the facilitators assessed the needs of the teachers and planned their sessions accordingly, focusing on inquiry and museum PCK. In addition, the museum educators aligned their PD sessions to the science and social studies curriculum for the City and suggested exhibits and Halls that the teachers could bring their classes to as a way to enrich their learning experiences. At times, the activities in the informal PD sessions were structured and individualized, thus focusing on a teacher's self-connection to the Museum. This approach allowed them free choice, but then focused the questioning on specific properties and classroom applications. Thus, a "hybrid" or "third space" (Calabrese-Barton & Tan, 2008; Gutierrez, 2002) definition of professional development in informal learning given by museums needs to be adopted. A link solely between schools and informal science institutions needs to be established and maintained through a hybrid working relationship among informal and formal institutions. Most museums have trouble communicating with teachers in elementary schools and informing them of the available resources they offer, and schools are often unaware of the rich resources that museums and museum educators provide. The addition of a science coach (the diagonal link) could bridge this gap, as shown as the third link in the CDLN model. For example, Tal and Steiner (2006) state:

> since the contact person in elementary schools is often not the science teacher, the museum has to find ways to communicate with other teachers in school, so they will know more about the museum, the learning activities, and the science curriculum. Teachers' workshops at a museum might also create better understanding of the different roles and contribute to the establishment of mutual planning of visits. (p. 42)

The researchers also comment that the "most common type of communication between the museum and elementary schools was administrative" (p. 40). The administration chooses a visit plan from the museum brochure and coordinates the time of the visit; by contrast, half of the secondary schools use museums, teachers' plans and pedagogical-content communication in their museum-based trips.

Similarly, another area of contrast that supports additional attention to professional development and relationships of informal institutions with elementary teachers are content expertise and content development. Most middle school teachers are certified in a subject area specialty (i.e., biology, earth science, chemistry or physical science), and have a higher confidence level in the science content but not necessarily the skills to teach; therefore, they may need to improve upon only one aspect of their teaching. By contrast, elementary teachers are certified as common branch, or referred to as generalists, with no particular specialty, and they need improvement in both science content and the ways in which to teach—and perhaps more so than other content areas. Middle school teachers might be more apt to continue dialogues with museums about pedagogical content knowledge in science. However, elementary schools usually lack a department chair for science, or a "point person" (or science specialist or science coach) who communicates with external organizations about professional development and relationships with informal institutions or universities.

Therefore, one way to accomplish active collaboration between elementary schools and museums is through a diagonal link using a science coach as an intermediary. Improving connections and empowering elementary teachers to seek and engage in the use of informal institutions and museums as cultural institutions (i.e., field trips, objects and artifacts) can increase museum access for underrepresented groups in large urban public schools and promote the development of social and cultural capital for teachers and students. Furthermore, in terms of cultural context, one potential positive implication is an opportunity to close the achievement gap and to open doors for minorities (i.e., students of color, those in low socioeconomic groups) and welcome them in public spaces, like cultural institutions such as natural history museums, that can expand their school-community connections.

Therefore, researchers and practitioners may need to think beyond the one-day science professional development sessions that are localized in one setting and move toward job-embedded and sustainable professional development that is inclusive of multiple, diagonal, and collaborative networks. Teachers are limited in their professional learning, which in turn impacts the learning of their students, when they only receive a vertical or top-down didactic approach to professional development. The findings of this research therefore argue for models of teacher professional development that provide opportunities for teachers to learn within diagonal relationships of support in teaching science and building teachers' science content and pedagogical content knowledge and self-efficacy.

Role of Science Coach in Elementary Education

This study defined science coach as a lead teacher or instructional specialist who serves as a full- or part-time staff developer for teachers solely in the subject area of science. The science coach conducts inquiry-based demonstration lessons, observes science lessons of teachers, gives feedback, and is a resource manager. The science coach is also a mentor using a bottom-up approach that identifies the root of teachers' difficulty and helps to train and prepare them for a successful lesson execution. There is a degree of trust and a mutualistic/collegial relationship that needs to exist in order for a science coach to be an effective staff developer and build capacity within an elementary school.

A coach differentiates professional development sessions and provides individualized support based on the teacher and his or her student population. The importance and pivotal role that the science coach played in this study was essential in order for the Collaborative Diagonal Learning Network to succeed. The way in which teachers, informal educators, and even the administration respond to the supportive role of a coach solidifies a diagonal connection, or reciprocal link among the active participants within the CDLN model.

Explicit Suggestions for Elementary Science Reform

I include this section on elementary science reform to offer a few propositions for professional development programs as policymakers, grant writers, district and school-based administrators make decisions that will ultimately affect the academic achievement of students in science, especially those living in urban school systems. With empowering and transformative policies, stakeholders of national and local science education reform can improve elementary teacher professional development school-wide (Mensah, 2010). Based on the abovementioned implications for professional learning and PD in informal and formal settings, the following suggestions are made as Science Technology Engineering & Mathematics (STEM) grants, No Child Left Behind (NCLB), and American Recovery and Reinvestment Act (ARRA) funds are decided and distributed:

- First and foremost, as stated as the overarching purpose of this research study, the formation of a Collaborative Diagonal Learning Network (CDLN): A CDLN program occurring during out-of-school time where teachers feel relaxed and enjoy full involvement in a professional learning community.

- Access for teachers and their students' families to informal institutions when not in school (free tickets after a museum visit to continue making connections).
- Partnerships between schools (science coach and teachers), higher education colleges and universities, and science-rich institutions to assist teachers with content knowledge, pedagogical knowledge, PCK, and curriculum alignment.
- Follow-up communications (email, mail, and other formats such as websites, blogs, wikis) by museum educators for pre- and post-museum trips to maintain ongoing dialogues, support, and sharing of resources among teachers, coaches, and institutions.
- Administrative buy-in—elementary school principals should not take a vertical learning approach when organizing and conducting PD. A diagonal relationship should exist where a science coach or school science teacher leader is the main point person communicating between teachers and outside informal institutions.
- Turn-key knowledge and resources of participants across the school or district community: Sharing at faculty meetings, school-based professional development, professional conferences, and district-level meetings to promote and advocate for teacher learning in-school and out-of-school.

Future Research

The results of this dissertation leave room for further research on school-museum partnerships, supportive relationships, and systemic professional development programs. Though limited in publication, the body of research that focuses primarily on school-museum relationships does not address interactions among coaches, museum educational personnel, and the way museums align with elementary school teachers' pedagogical content knowledge and the curricula they have to teach (American Association of Museums, 1992; Hofstein & Rosenfeld, 1996; Tal & Steiner, 2006).

Several challenging questions have yet to be addressed in science education research that arose from the findings presented here. For example, a future study can address the roles and responsibilities of the mentor links in the CDLN model: how can science coaches and museum educators nurture a mutualistic relationship that fosters in-service teacher education in urban public schools? Although the current study addresses each individual link concentrating on the PD facilitated by the science coach and the museum educators, no data were collected that focused solely on the role and expectations, planning, and self-reflections of the mentors. Some questions around these issues are: What is the process for mentors (science coach and museum educators) to plan each session, keeping in mind individual and group needs? How does this form of teacher-centered professional development (Moore, 2008a) allow the mentors to meet the needs and goals of science reform? Based on feedback from the teacher participants, in what ways does the science coach differentiate lesson modeling for each teacher's individual needs, thus allowing each teacher to develop PCK and self-efficacy? How does the museum education department evaluate its role in this diagonal professional learning model? How will the informal institution (museum educators and education department) change/revise their professional development in terms of self-evaluation (and teacher feedback)?

In addition to these questions on mentoring, a few lingering questions include reasons for teacher buy-in, and even their change in anxiety over the use of museum trips for student learning and the long-term effects of teacher participation in diagonal learning models and collaborative support networks. Some questions are: What factors contribute to an established level of trust among all participants in the professional development? What are some reasons for teachers' changes in behavior or thinking about changes in practice, views of informal institutions, science, or student learning? What are some reasons for increases in PCK during science lessons and in museum education, or the extent to which activities promote the most growth in self-efficacy and changes in teaching practice (Gunning & Mensah, 2010)? What long-term effects does PD have on teachers, despite its short duration?

Conclusion

If one significant aim of education is to create and maintain a pool of highly effective teachers in elementary schools, it is necessary to open up opportunities for professional learning. A solid elementary science foundation sets the stage for the skills and knowledge needed for science learning in the upper grades (Mensah, 2010). Without this early foundation set forth by the teacher, a student is at a significant academic disadvantage, and this is even more challenging for students in urban schools that are highly under resourced. This dissertation sought to provide a model to empower elementary teachers and administrators to promote the goal of high-quality professional development. By demonstrating a new context and form of professional development, the findings advocate strongly for a Collaborative "Diagonal" Learning Network, or CDLN model, that supports the notion that relationships, communication, and knowledge grew out of a diagonal partnership among science experts, teachers, and informal institutions.

Interestingly, an emergent question from the study—what long-term effects did the PD have on the teachers despite its short duration—has been answered recently by pure coincidence. In a conversation with a colleague, I inadvertently discovered that two of the teacher participants in this study (Maria and Ada) enrolled in a graduate-level course called *Science in the City*, which incorporates informal learning with teacher education. Some classes are held at the Museum in order for in-service teachers to learn how to go on field trips and use museum resources, very similar to the model presented here; however, the formal higher education aspect of the course does not lend itself to job-embedded coaching and follow-up. To this extent, I see hope in these action-oriented teachers who continue to extend their knowledge base and curiosity. I am even more curious to learn how short-duration professional development serves as an impetus for teachers, particularly elementary school teachers, to seek additional support in their continual growth to become highly effective teachers of science. Thus, an outcome of this dissertation study, and the model promoted here, seems to foster future research on meaningful professional development models that promote sustained learning outcomes and collegial community through school-museum-teacher partnerships.

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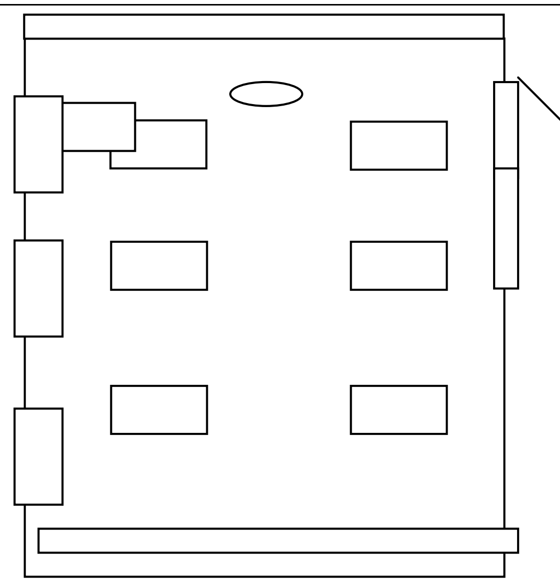
APPENDIX A

Science Lesson Observation Protocol Template

Length of Lesson: ____ Minutes	
Descriptive Notes	**Reflections**
Learning Objective(L.O):	
Motivation:	
Mini-Lesson Presentation:	
Student Activity (Description/Materials Management/Grouping):	
Lesson Assessment:	
Student and/or Teacher Share:	
Closure (Summary to L.O):	
	 Sketch of Classroom

APPENDIX B

Formal and Informal Questionnaires (pre/post)

Teacher CDLN Informal Questionnaire
Quality of the Museum-Based Professional Development [pre]

This questionnaire rates the quality of Museum-Based Professional Development (PD). The questionnaire contains 6 open-ended questions. Please write your response below each question. The questionnaire should take approximately 15 minutes to answer.

Please answer honestly as you critique museum-led workshops. Answer the questions by yourself and refrain from talking to your colleagues as you complete the questionnaire. Thank you for your honesty, advice, and participation!

1) Have you ever attended workshops sponsored by an informal institution (e.g. museum, science center, park, aquaria)? _______________

—If so, list the informal institution/s that sponsored it/them and continue to question 2.

—If not, would you want to attend? _____

▪If you answered no, please answer *why* here and skip to the comments section.

▪If you answered yes, please continue to question 2.

2) How helpful do you consider most informal institution-sponsored workshops you attended or would want to attend?

3) What new science concepts did you learn?

4) Was this workshop helpful for your teaching?

5) Would you go to the American Museum of Natural History (AMNH) on your own? Why or Why not?

6) What museum resources, if any, did or would you use with your class?

Please add any additional comments.

Teacher CDLN Formal Questionnaire
Quality of the School-Based Professional Development [pre]

This questionnaire rates the quality of School-Based Professional Development (PD) from the science coach at your school. The questionnaire contains 4 open-ended questions. Please write your response below each question. The questionnaire should take approximately 10 minutes to answer.

Please don't be shy to answer honestly as you critique science coach-led workshops. Answer the questions by yourself and refrain from talking to your colleagues as you complete the questionnaire. Thank you for your honesty, advice, and participation!

1) Have you ever attended PD or workshops sponsored by the science coach at your school? ______

▪If you answered no, please answer *why* here and skip to the comments section.

▪If you answered yes, please continue to question 2.

2) If so, how helpful do you consider most science coach led PD you attend?

3) What new science concepts did you learn or have clarified?

4) Was this science coach-led PD helpful for your teaching? Why or why not?

5) Based on science coach-led PD, what museum resources, if any, have you used with your class?

Please add any additional comments.

Teacher CDLN Informal Questionnaire

Quality of the Museum-Based Professional Development [post]

This questionnaire rates the quality of the Museum-Based Professional Development (PD) you received from the educators at the American Museum of Natural History (AMNH). The questionnaire contains 6 open-ended questions. Please write your response below each question. The questionnaire should take approximately 15minutes to answer.

Please answer honestly as you critique the museum-led workshops. Answer the questions by yourself and refrain from talking to your colleagues as you complete the questionnaire. Thank you for your honesty, advice, and participation!

1) How helpful did you consider the museum-sponsored workshops you attended?

2) What new science concepts did you learn or have clarified?

3) Were the AMNH workshops helpful for your teaching?

4) Would you have come to American Museum of Natural History (AMNH) on your own? Why or Why not?

5) Will you continue to visit AMNH? Why or Why not?

6) What museum resources, if any, will you use with your class?

Please add any additional comments.

Teacher CDLN Formal Questionnaire

Quality of the School-Based Professional Development [post]

This questionnaire rates the quality of the School-Based Professional Development (PD) you received from the science coach at your school. The questionnaire contains 4 open-ended questions. Please write your response below each question. The questionnaire should take approximately 10 minutes to answer.

Please don't be shy to answer honestly as you critique the science coach-led workshops. Answer the questions by yourself and refrain from talking to your colleagues as you complete the questionnaire. Thank you for your honesty, advice, and participation!

1) How helpful do you consider the science coach-led PDs you attended?

2) What new science concepts did you learn or have clarified for you today?

3) Were the science coach-led PDs helpful for your teaching?

Please add any additional comments.

APPENDIX C

Individual Interview Protocol

PRE/POST LESSON OBSERVATON
SEMI-STRUCTURED PROTOCOL

TIME OF INTERVIEW: ___:_____
DATE: ____/_____/_____
DURATION: ____minutes
INTERVIEWER:
INTERVIEWEE:

State, "I am interviewing you today to find out how your science lessons are going, in terms of your content, how your teaching the lessons with the new curriculum, and how you want to be supported as a teacher. The interview should take no longer than 15 minutes. Answer honestly and if you need to stop for any reason or have any questions, just let me know."

QUESTIONS:

1) How are your science lessons going?

2) How has your science teaching been since we started using the FOSS/Harcourt curriculum?

3) Do you like the new curriculum? Why or why not?

4) Have you been given support around the science knowledge you need to teach for the units?

5) Have you been given support around using the science materials for the units?

6) Have you been supported with using your own science knowledge with implementing the curriculum?

7) If you have been not supported, what areas do you need assistance?

→Do you need any help with…
- the background science content?
- lesson plans?
- materials or any other resources?

Thank you for your honesty, advice, and participation.

APPENDIX D

Teachers College IRB Consent Form Approval

TEACHERS COLLEGE
COLUMBIA UNIVERSITY
OFFICE OF SPONSORED PROGRAMS
BOX 151

Institutional Review Board

December 22, 2009

Natasha Cooke-Nieves
1431 President Street
Brooklyn NY 11213

Dear Natasha:

Thank you for submitting the modification to your study entitled, *"A Collaborative "Diagonal" Learning Network: The Role of Professional Development in Elementary Science Reform"*; the IRB has determined that your study remains exempt from review.

Please keep in mind that the IRB Committee must be contacted if there are any changes to your research protocol. The number assigned to your protocol is **09-270.** Do not hesitate to contact the IRB Committee at (212) 678-4105 if you have any questions.

Best wishes for your research work.

Sincerely,

William J. Baldwin
Vice Provost
Interim Chair, IRB

cc: File, OSP