

ABSTRACT

Title of Dissertation: AN EXAMINATION OF SCIENCE
TEACHERS' LEARNING IN A
LABORATORY-BASED PROFESSIONAL
DEVELOPMENT PROGRAM

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Professional development generally refers to the collection of activities that systematically increase teachers' knowledge of academic subjects and advance teachers' understanding of instructional strategies. Given the complexity of the reform initiatives for science education in the United States of America as set forth by the American Association for the Advancement of Science (AAAS), and the *National Science Education Standards* (NRC, 1996), professional development might provide a bridge for aligning teacher practice with national standards (Loucks-Horsley, 1995). However, the current model of professional growth, focused largely on expanding a repertoire of skills, is not adequate (Little, 1993). Understanding teacher learning theory and utilizing research on pedagogical content knowledge (PCK) could be the differentiating factor for science teacher professional development; if utilized in design and evaluation, they may

promote both knowing science in context and knowing how to tailor science learning to the needs of students (Shulman, 1987).

The purpose of this study was to investigate how the Laboratory Science Teacher Professional Development Program (LSTPD), a three year professional development model that immerses teachers in learning science content through inquiry, impacts teachers' learning and classroom practice. It first aimed to analyze teacher learning and PCK; second, it examined their views on professional development; and third, whether they anticipate adapting their practice to include facets of their laboratory experience. Participants were teachers in their second or third year of participation in LSTPD. The study followed a qualitative case study design and made use of in-depth interviews and observations to examine teachers' knowledge, beliefs, and practice. The study drew on a constructivist framework. Findings demonstrated that teachers' understanding of content, inquiry, and science as a living enterprise were greatly increased, and that teachers generated goals for practice that echoed their new understandings. Further, teachers articulated how they connected LSTPD to their classrooms, fueling further discussion of the role of PCK in their experience. This study has greater implications for the design of sustained research-based professional development experiences in promoting learning in teachers, and inquiry techniques in classrooms.

AN EXAMINATION OF SCIENCE TEACHERS' LEARNING IN A
LABORATORY-BASED PROFESSIONAL DEVELOPMENT PROGRAM

By

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Dedication

This work is dedicated to my husband Brian, who provides me with unending love and support, and to my family, particularly my mother Ms. Christine Cook, who always put education first. I also thank the professionals with whom I have had the privilege of navigating the trenches of public schooling. There is no greater battle worth fighting than that of improving the educational experiences of our children.

“Professional development for teachers should be analogous to professional development for other professionals. Becoming an effective science teacher is a continuous process that stretches from pre-service experiences in undergraduate years to the end of a professional career.”

- National Science Education Standards, p. 55

“When laser eye surgery was a new technology, doctors refusing to learn the new technique would never be able to maintain their practice. They have to learn the latest and greatest technology, or they would longer be in business. The field of medicine grows and advances and doctors must grow and advance with it. Why don’t we view teaching through the same lens?”

- John Quinn, Secondary Science Coordinator, Howard County Public School System,
Howard County, Maryland

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Chapter 1: Introduction

“What teachers do is not a formulaic following of rules, but nuanced, professional practice in which teachers constantly make important decisions and judgments in how they interact with their students to facilitate their learning. What this means is that if teachers are not involved, educational reform will not happen” (Hewson, 2007, p. 1180).

Overview and Purpose

The current century is marked by rapid advances in science, engineering, and technology. The United States is struggling to compete with countries from around the world, particularly in Asia, to maintain high standards of scientific literacy and encourage students to pursue careers in scientific fields. To address this concern, curricular initiatives in American schools were enacted by the federal government and other special interest groups. In 1990, the American Association for the Advancement of Science (AAAS) published *Science for All Americans*. This text was based on four basic beliefs:

1. The scientifically literate person is one who is aware that science, mathematics, and technology are interdependent human enterprises with strengths and limitations.
2. There is a body of basic scientific knowledge about the world that provides perspective for human enterprise.
3. The natural world, with its vast diversity, is inherently connected to our everyday lives.
4. Scientific knowledge and scientific literacy are habits of mind.

If the scientific community believes that there is great benefit in all students understanding science, it then becomes the job of the science teacher to introduce science content and context to young learners. To accomplish this, teachers need to be educated in ways that are consistent with the vision and goals of increasingly important science education standards. For teachers to meet the demands of the current technological society and advance students' achievement in science, they must be fully qualified to deal with ever-evolving content, and ever-changing students (Darling-Hammond, 2000). Professional development is one significant mechanism for maintaining a high standard in science teaching.

Science teachers need ongoing opportunities throughout their professional careers to build their understanding of evolving concepts. These opportunities, coupled with pedagogy initiatives, are collectively viewed as professional development. Hewson (2007) stated,

First, [professional development] is about teachers and their teaching activities involving curriculum, instruction, and assessment; about their students and their learning; and about the educational system in which they practice. Second, it is about teachers being professionals who have an extensive knowledge base of conceptions, beliefs, and practices that they bring to bear on the unique complexities of their daily work lives, a knowledge base that is shared within a professional community. Third, it is about teachers as adult learners who have an interest in and control over the continuing development of their professional practice throughout their working lives, a process that is greatly facilitated by working in community with their peers. Finally, it is about science and the

epistemologies, methodologies, and bodies of knowledge about the natural world that give scientific disciplines their distinctive character (p. 1181, 2007).

Teachers participate in various types of professional development, including district-sponsored day-long workshops, graduate courses, summer or weekend programs offered by outside organizations, and professional organization memberships. Much informal professional development takes place in the school setting, where teachers engage in collegial conversations over the lunch table or during shared planning periods. Professional development generally aims to increase a teacher's understanding of curricular reforms for their district, classroom management, or student assessment, all with the ultimate goal of increased student learning (Hewson, 2007).

Reform initiatives in science teaching since the No Child Left Behind legislation are causing a shift from teaching styles dependent on memorized facts to more progressive, problem-solving oriented lessons in all science subject matter (Loucks-Horsley, Hewson, Love & Stiles, 1998). This means that teachers need to learn how to approach teaching in new ways. The No Child Left Behind (NCLB) Act of 2001 not only necessitates professional development, it mandates it. Little guidance is provided, however, as to what that professional development looks like, which demands turning to research on what is most effective. Researchers are just beginning to understand what and how teachers learn from professional development (Garet, Porter, Desimone, Birman, & Yoon, 2001). Borko (2004) found that professional development has the potential to promote high quality teaching by expanding subject matter knowledge and instructional practices, promoting professional communities, and allowing for reflection and discussion on artifacts related to practice. Four important factors were identified by

Hewson's review of research (2007) that further emphasized the need for professional development in teaching: (1) curricula is not teacher-proof; (2) reform initiatives cannot just be taught in teacher education programs or there is a risk of missing the largest contingent of the workforce; (3) not all teacher certification programs are addressing reform initiatives; and (4) educational contexts change, so even the most qualified teachers may need to reconsider their practice.

Bell and Gilbert (1996) found that professional development can be a particularly strong method for engaging science teachers in new ways of learning that best encourage student achievement. They found that professional development activities must focus on personal development, social development and professional development. Bell and Gilbert conceptualize teachers moving through three phases for each kind of development. Teachers develop personally when they examine aspects of their practice that are problematic, then acknowledge the restraints inherent in teaching, and finally feel empowered to move beyond these. They develop socially by first identifying the social isolation inherent in teaching and seeking out support in colleagues, then recognizing the value of collaboration, and ultimately initiating that collaboration. Professional development emerges through trying out new activities, to then developing a more coherent professional practice, and eventually seeking out or initiating professional development activities.

Professional development initiatives are a core piece of national standards for science education. More than a decade ago, AAAS published a set of standards known as *Benchmarks for Science Literacy* (1993) and the National Research Council published the National Science Education Standards (1996) (Appendix C). "These reform efforts are

inseparable because the projects are interrelated. Key leaders have contributed to the work of multiple projects and each organization has built on the work of the other” (Ellis, 2003, p. 39). These guidelines marked an important shift in science education; namely, they established that all students can learn science in the right context; science should be taught in depth rather than through memorized facts; literacy should include history and the nature of science; curriculum, instruction and assessment should be linked; and national, state, and local curricula should align (Ellis, 2003, pp. 39-40). To accomplish these goals while simultaneously teaching specified content, teachers are asked to create a learning environment where students can construct their own understanding by engaging in genuine inquiry; teachers would be facilitators of learning rather than dispensers of information (Horizon Research Inc., 2003). A review of literature conducted by Horizon Research Inc. (2003) shows that external and internal issues impede implementation – external meaning state testing, time, and materials, and internal meaning they lack an in-depth understanding of what it means to implement standards or reform-based education in science. However, professional development was shown to have a positive impact on teachers’ perceptions of content preparedness and pedagogy, and the more professional development that teachers receive, the more their practice is reformed.

Given that these reform initiatives are more than a decade old, their impact on science instruction today may be different than the first years of their implementation. The National Research Council’s Committee on Science Learning, Kindergarten through Eighth Grade published *Taking Science to School* (2007) in which they examined three questions: “(1) How is science learned, and are there critical stages in children’s development of scientific concepts? (2) How should science be taught in K-8 classrooms?

(3) What research is needed to increase understanding about how students learn science” (Duschl, Schweingruber, & Shouse, 2007, p. 1)? They concluded that students learn science differently than what was theorized 30-40 years ago, and that science curricula should be redesigned to demonstrate a blend of inquiry and content, teacher-directed experiences and student-led investigations or discussions, and a spiraling of concepts over successive grade levels rather than a list of unrelated, fragmented topics. Where does this leave teachers? Most were not taught this way in their own primary and secondary science experiences, nor was this the model for their teacher preparation programs. Duschl, Schweingruber, & Shouse’s (2007) review states that teachers need to have a broader but deeper understanding of science, must understand new research on child development and their capabilities for learning science, and have specialized knowledge about how to teach science. They call for dramatic changes in professional development to address these needs.

The National Science Foundation and the US Department of Education have funded hundreds of professional development initiatives for science teachers in the past twenty years (Committee on Biology Teacher Inservice Programs, 1996). While volumes of research studies exist that examine various aspects of particular professional development programs, those whose ultimate goal is understanding the impact on teacher learning are few. It is for this reason that I pursued my study of the role that a professional development program, designed to revitalize the research interests of science teachers and improve their content knowledge and scientific skills, had on science teachers’ learning.

Biography of the Researcher

School was always how I defined myself. I was never the athlete, nor was I the artist. While I can sing and play the piano, my cousin, a Broadway star, always took the limelight. School was, and is, where I excelled. It was never a matter of being a prodigy or a gifted learner – looking back, knowing what I know of these labels now, I was neither. I was, however, in love with learning. I enjoyed homework, I looked forward to every subject, and I admired my teachers. In high school, when given the chance to complete a year-long independent study, I studied music education. Obviously, one could conclude that I went to college to become a teacher – and they would be wrong.

I completed an undergraduate degree in chemistry, largely because I liked every subject, and it seemed to me that science would be the most interesting for the rest of my life, and potentially the most lucrative. I found, however, that I dreaded long, lonely hours in the lab and often wondered why I needed to understand the ultimate objective of my experiment. As irrational as it seemed, I felt that if I was not studying something that contributed to the greater good of humanity, it was unnecessary. My struggle showed in my academic performance and my feelings of uncertainty towards the future. For the first time, the security blanket of school that had warmed me since kindergarten did not feel safe. In my junior year, I took an education course – my first of two – and realized that I had been lost as a learner in pure chemistry, and found myself as a learner in science education.

Immediately after graduating, I started a masters-certification program in teaching. I was re-energized, and one year later, started teaching in the same county from which I graduated five years earlier. I spent my first six years teaching primarily

chemistry, but also taught an introduction to chemistry and physics course, and Advanced Placement environmental science. During that time, much changed in my county. The core chemistry curriculum was lengthened and assessments were written to gauge student understanding at the end of each quarter – requiring the teacher to cover a specific list of objectives in a specific time frame. What little professional development we had (two five-hour sessions per school year), specific to our content, was spent reviewing changes to the curriculum, and reading the assessments for errors before they went to print. I assumed this was “normal” and began seeking out opportunities outside of my district that would fulfill my other interests in my profession. One such opportunity was a graduate program – a doctoral program – in curriculum and instruction. I had never read educational research before, and was resistant in admitting its utility and importance in understanding education. One pervasive issue for me in that research was the lack of the teacher’s voice.

As a teacher, I want to be heard, and for my opinions to be represented when decisions are made regarding my job. With the exception of pointing out editing mistakes on local assessments, I never felt professional development in my district offered me an outlet for collegial discourse, content growth, or exposure to new teaching techniques or understandings about our students. I found all of this in my doctoral program, and began connecting what I learned there to other opportunities for professional development. I wanted to find a way to both examine professional development and give teachers a voice, which led to this study. Here, I examine one specific program with the goal of understanding its impact on the teachers involved. I

give them a voice, and in doing so, fill in a gap that I, as a practicing teacher, saw in much of existing research in my field.

For me, being a chemistry teacher means that I have a unique understanding of my content, and how to teach it. It means that I can help students construct new understandings in chemistry in a way that the general population cannot. It means that I have an obligation to maintain my understanding of the content of chemistry, and the pedagogy of ever-changing classroom teaching.

Unfortunately, I believe that many teachers are not challenged in professional development experiences in ways that make them think deeply about their roles as classroom leaders and facilitators of learning, much like my ten hours of content development each year. They have little time for reflection and discourse. They have little awareness of the changing tides of best practice, and are not currently involved with their content. Any new methods or discipline-related updates that they learn are the result of professional development. This can be as little as one day of time twice per year, as it is in my district (or nothing, as discussed by one of the participants in this study). Because of the budget and time restraints placed on many districts, professional development becomes less important than high-stakes assessments and bridging the learning gap in reading and mathematics (although it seems that professional development could assist with both).

Given that local districts are not able to meet all of the professional needs of their teachers, it is imperative that outside organizations, such as private businesses, universities, and government agencies, assist with their professional growth (Committee on Biology Teacher Inservice Programs, 1996). Science, in particular, is a field that is

ever-changing. Just ten years ago, climate change and global warming were far from the everyday vernacular of laymen, hybrid cars were something of a futuristic oddity, and Pluto was universally referred to as a planet. Teachers often have no connection with the latest areas of research, the techniques, and the methods for that research, and the overall goal of the research. I, for example, only learned of advances in scientific research through reading the newspaper, or a number of general readership magazines. I had not completed sustained laboratory research since college, and had no clear understanding of how to connect the advances I read about to the finite details of my curriculum.

Collaborative partnerships that provide intensive experiences for science teachers could bridge that gap, and did, for me. My district neither had the monetary resources, nor the facilities, to allow teachers to engage in real-time science research, nor in my opinion, should they have been expected to. They are in the “business” of education – of curriculum development and assessment. Where could a teacher like me go to gain laboratory experience? He or she would need to seek out universities, museums and science learning centers, and government laboratories.

Since my second year of teaching, I have participated in a number of professional development programs sponsored by outside organizations. In addition to enrolling at the University of Maryland in 2002, I also attended the REACTS (Reaching Educators for the Advancement of Chemistry Teaching Statewide) Conference. It allowed me to collaborate with Maryland chemistry teachers in a variety of workshops ranging from curriculum to technology. In 2003, I participated in two professional development opportunities sponsored by Johns Hopkins University. The first, Materials Research Science and Engineering Center, allowed me to participate in hands-on activities with

scanning electron microscopy, transmission electron microscopy, crystallography and x-ray diffraction, microelectronics, optical and e-beam lithography, and phosphors for display technology. The second, QuarkNet, was a week-long instructional opportunity on fundamental interactions, motion of charged particles in electric and magnetic fields, energy and momentum conservation, electric circuits, fundamental particles, and radioactivity.

The summer of 2004 was particularly exciting in my professional journey, as it was the beginning of my experience in Berkeley, California – the subject of this research. I spent six weeks at the Lawrence Berkeley National Lab as a research associate in the Environmental Energy Technologies Division. I analyzed atmospheric chemistry and visibility data for federally protected areas, worked with other teachers from around the country, and generated a professional development plan (Appendix G) that included a mini-grant proposal for purchasing teaching materials and expenses related to attending professional conferences. I returned from Berkeley in time to attend a one-week course through the College Board on teaching AP Environmental Science. I then returned to California for another professional opportunity - Science Education for New Civic Engagement (SENCER). I was asked to be involved in a collaborative project with the chemistry department of Gettysburg College to develop a first-year chemistry course that integrates curricular objectives with civic engagement. In 2005 I attended my first national conference – the National Science Teachers' Association annual conference in Dallas, Texas. That summer I was married, and took a brief hiatus from professional development.

In June of 2006, I returned to Berkeley for eight weeks to work in the same lab division, this time studying transport properties in combustion modeling of simple fuels by using viscosity data to extract potential constants for the intermolecular potential for binary systems. I also had the opportunity to attend more professional conferences – the National Science Teachers’ Association area conference in Baltimore, Maryland, and the Maryland Educators of Gifted Students annual conference in Clarkesville, Maryland. I finished that school year by attending the 2007 National Association for Research in Science Teaching annual conference in New Orleans, Louisiana. Since that time, I have transitioned from teaching science to running a research program for gifted and talented students in my district and am seeking out new opportunities to grow in this field. One of those opportunities will manifest in June of 2008 – a Fulbright seminar in Germany designed to open global communication on professional development.

I sought out these experiences because of my own desire to grow in my understanding of science, and to expand my network of colleagues. I think that I am not unique to my field in this desire to learn more about what I do, and how I can do it better. In my experience, many teachers crave professional development experiences that are meaningful and fulfilling. Research, however, offers little to support this statement. Combing through journals and educational databases, I realized that professional development research is largely concerned with the programmatic impact on student achievement rather than the experience of the teacher. While there is no fault in this, it begs the question again of who is giving a voice to the teacher participant – a voice that does not merely speak to test scores or lesson plans, but the feeling of being a professional. I think that teachers want to feel like they are part of a larger professional

community. Teaching can be so solitary – one individual in one classroom for the entire day. I was fortunate to teach chemistry in an environment that supported collaboration. Teachers spent time together during planning periods, ate lunch together, and met after school. Some of these interactions were social, but all, in some way, connected to the classroom. As a result, I felt safe – I could try new lessons and then discuss their successes and failures with my fellow teachers. In my current position, I work alone – I have no interaction with the colleagues in my building. The conversations in which I engage daily are with adolescents. I see very clearly now how important those unstructured times were, and wonder what schools and principals can do to support professional collaboration in their schools. My professional growth experiences, in school and across the country, provided a network. More importantly, I believe they provided inspiration.

The program that is the focus of this study, the Laboratory Science Teacher Professional Development Program (LSTPD) in Berkeley, California, is an intensive research experience for science teachers at one of the most eclectic labs run by the Department of Energy. At the Ernest O. Lawrence Berkeley Lab, research is conducted in a variety of fields, including quantitative biology, nanoscience, energy systems, environmental studies, and the use of integrated computing. Teachers are placed with researchers who embrace the mission of outreach. During the summer of 2004, I played a small but significant role in attaining visibility data in Wyoming and Colorado based on measures of criteria pollutants and airborne particulate matter. In 2006, I collected data on transport phenomena to be used in combustion modeling. In addition to doing research, all of the teachers work together, weekly, to share experiences, swap lesson

plans and activities, and begin discussing how their work at the lab will change their own teaching. I had never lived away from home for professional development. I had never worked with teachers from across the country, whose experiences were so different, and yet so similar to my own. Never had I been paid a professional wage and provided with funds to purchase items for my classroom for such an experience. I worked with eminent scientists who valued my opinion and my contribution, and were often astounded at my descriptions of day-to-day life in the classroom (descriptions that were in no way provocative to me). I provided them with a sense of what is really happening in science education, and they provided me with a sense of what is really happening in science research. It was a life-changing experience.

The head of science in my district once said to me, “If medical doctors refused to learn the latest techniques in their field, they would lose their clients to more capable, current professionals.” I believe we should approach teaching in the same way. We have an obligation to our students to have an understanding of the latest advancements in our field, both in content and in pedagogy. It is my belief that in order to create a scientifically literate cadre of teachers, we must first examine how teachers learn, and then provide professional development initiatives that facilitate that learning. How do we ensure that teachers gain new understanding? We first examine what they need to know, and then how we can best provide it. It is attempting to answer this question that I have chosen to focus my doctoral study on an investigation of professional development in terms of teacher learning.

Before one can fully understand my intent in illuminating these teachers’ experiences in the LSTPD program, I must first clarify my own understanding of what it

means to learn, to know, and to understand. Learning is more than acquiring facts; it is the development of skills, behaviors, values, and ideals. Learning comes from experience, and is best facilitated by teaching and interacting with material and ideas. Knowledge is a collection of information, generally learned or experienced. Acquiring knowledge is a complex process, and for a concept or behavior to be considered knowledge, it must be something a person understands. I regard people as knowledgeable when they not only know information en masse, but can also articulate that information in appropriate settings. This, I believe, is understanding – the ability to connect bits of knowledge and apply them in the appropriate settings. How teachers learn, understand, and know was of keen interest in this research study.

Statement of the Problem

We live in a world that has become increasingly technological. There are a growing number of technical endeavors requiring skills in science, technology, engineering and math. The future of any society, America's or otherwise, rests upon its ability to adapt in an increasingly industrialized world. Scientific literacy is vital in preparing students to examine local and global problems, to identify the dependency of living things on each other and their environments, and to work logically and systematically through problems (AAAS, 1989). To that end, there is a central movement in science education to actively engage students in methods of inquiry and collaboration (NRC, 1996). As Lieberman (1995) stated, "...what everyone appears to want for students – a wide array of learning opportunities that engage students in experiencing, creating, and solving real world problems, using their own experiences, and

working with others – is for some reason denied to teachers when they are the learners” (p. 591).

Learning, simply stated, is gaining knowledge – whether through study, experience, or exposure. Teachers who are learning, continually and actively construct their views of education, see themselves as lifelong learners, and look for ways to effectively transmit these same expectations to their students. They need to reevaluate their own value systems and be willing to challenge their existing frameworks (Fullan, 1993). This is the evolution of the field. Effective science teachers need a strong science background, as well as a deep understanding of pedagogy (Shulman, 1987). This knowledge base develops from four sources: (1) scholarship in science; (2) the materials and setting in which science is taught; (3) research on schooling, social organizations, human learning, and other cultural phenomena that affect what teachers can do; and (4) the wisdom of practice (Shulman, 1987).

The unique body of knowledge held by content teachers was characterized in the 1980s by Lee Shulman. The blending of subject matter understanding with knowledge of pedagogy is referred to as pedagogical content knowledge (PCK). Teachers with well-developed PCK use analogies, illustrations, examples, explanations, and demonstrations in a way that makes subject matter comprehensible to others. When teachers make instructional decisions, Shulman (1987) suggests that they draw from many types of knowledge: (1) knowledge of subject matter; (2) knowledge of curriculum; (3) knowledge of learners; (4) knowledge of educational aims; (5) knowledge of other content; (6) pedagogical content knowledge (PCK); (7) and general pedagogical knowledge. Only PCK is unique to the subject matter teacher.

The special amalgam of content and pedagogy that is uniquely the providence of teachers, their own special form of professional understanding... pedagogical content knowledge... identifies the distinctive bodies of knowledge for teaching. ...Pedagogical content knowledge is the category most likely to distinguish the understanding of the content specialist from that of the pedagogue (Shulman, 1987, p. 8).

The development of PCK throughout a teaching career depends on the opportunities a teacher has to grow professionally. Professional development generally refers to the collection of activities that enhance a teacher's professional growth. Loucks-Horsley, Love, Stiles, Mundry, & Hewson (2003) suggests that there are a number of professional development strategies aimed at improving the professional learning experience of science teachers, including (1) aligning and implementing curriculum, (2) creating collaborative structures, such as partnerships with businesses, industry, or universities; (3) examining teaching and learning through action research, or case study; (4) immersion experiences based on inquiry and real-world scientific questions; (5) practicing teaching through coaching, demonstrations, and mentoring; and (6) mechanisms whereby teachers become the professional developers, sharing their knowledge of technology, content, and practice through workshops, institutes and seminars. Traditional approaches include one-stop workshops, or top-down models where teachers are recipients of methods and materials, but played no role in their development (Clarke & Hollingsworth, 2002).

Collaborative, reform models of professional development tend to focus on the development of communities where teachers engage in some kind of authentic activity

(Butler et. al., 2004). Science education, as a field, has a set of national recommendations for fostering professional growth. The National Research Council recommends in the *National Science Education Standards* that science teachers actively engage in investigating phenomena, addressing issues in science, building their own understandings, reflecting on the process of inquiry, and working collaboratively during professional development (NRC, 1996). In light of this, a great deal of research has been done to signify what kinds of professional development translate into best practice (Loucks-Horsley et al., 2003). For example, professional development should provide more than just procedural skills – there should be a focus on conceptual change (Butler, Lauscher, Jarvis-Selinger, & Bechingham, 2004). Butler et al. also suggest that teachers will respond to collaborative activities with greater success, be it in working with university researchers to understand intersections between formalized knowledge and practical knowledge, or collaborating with colleagues on instructional innovations.

Birman, Desimone, Porter, & Garet's (2000) analysis of professional development opportunities identified three structural features for professional development – form, duration, and participation - and the core features necessary for the success of those structural features – content focus, active learning, and coherence. The form of professional development may be traditional workshops and in-service, but only if it allows time, activities, and content necessary for increasing their knowledge and fostering meaningful change in the classroom. The same is true for duration – longer experiences provide more time for the core features, but shorter programs can be effective if these are present. Finally, professional development is more effective if participants are from same department, subject, or grade. *Content* refers to enhancing the

discipline knowledge of the teacher, *active learning* encourages teachers to become more engaged in discussion, planning and practice, and *coherence* refers to the extent to which professional development experience is part of the integrated program of teacher learning. “[By] focusing on specific mathematics and science content, by engaging teachers in active work, and by fostering a coherent set of learning experiences, a professional development activity is likely to enhance the knowledge and skills of participating teachers and improve their classroom teaching practice” (Birman, Desimone, Porter, & Garet, 2000).

Little (1993) argued that given the complexity of our present reform initiatives, our current model of professional growth, focused largely on expanding a repertoire of skills, is not adequate. Instead, professional development should be tested against these principles: (1) does it offer meaningful intellectual, social, and emotional engagement with ideas, with materials and with colleagues both in and out of teaching; (2) does it take explicit account of the contexts of teaching and the experiences of teachers by encouraging focused study groups, teacher collaboratives, and long-term partnerships; (3) does it allow for informed dissent; (4) does it place classroom practice in the larger contexts of school practice and the educational careers of children; (5) does it prepare teachers to employ techniques and perspectives of inquiry; and (6) is there a balance between interests of individuals and those of institutions (Little, 1993).

Clarke & Hollingsworth (2002) suggest an Interconnected Model of professional development, where the teacher is impacted by two domains – the external domain, and the teacher’s professional world of practice. The professional world of practice encompasses the, “teacher’s professional actions, the inferred consequences of those

actions, and the knowledge and beliefs that prompted and responded to those actions” (Clarke & Hollingsworth, 2002). This second domain is characterized by personal knowledge and beliefs, professional experimentation, and consequences. External factors are anything outside of the teacher’s professional world. All of these are inter-connected in that change in one triggers action or reflection in the others. What this means for professional development is that multiple variables must be considered when making decisions about what kind of professional development will translate into best practice, as each overlap.

Drawing on work by Loucks-Horsley et al. (2003), Jeanpeirre, Oberhauser, & Freeman (2004) deduced from their study of two professional development programs that three characteristics are necessary for effective professional development (e.g., professional development that leads to changes in practice).

(1) “deep” science content and development of science process skills with numerous opportunities for teachers to practice using integrated science processes and research skills; (2) clear accountability requirements of teachers, where they demonstrate competency in a tangible and assessable way (i.e., a product of their learning is produced, which is accessed at specified standard of acceptability); and (3) developers and providers of professional development experiences with high expectations for teacher learning who can facilitate multifaceted experiences that allow teachers to demonstrate their learning (Jeanpeirre, Oberhauser, & Freeman, 2004).

The purpose of this study was to increase the understanding of how teachers’ learning was impacted by their participation as researchers in a content-rich professional

development program. I chose to examine how teachers change in their profession and what professional development can do to facilitate that change. Additionally, the teachers were asked to articulate how their participation impacted their classroom practice. The professional development program studied aimed at connecting content and pedagogy through science research experiences. What follows are the research questions, review of literature, theoretical framework, and methodological considerations for a study of the program currently running through the auspices of the Department of Energy. The program will be discussed in full, as will the findings of the study, including implications for further work.

Research Questions

This study addressed the central research questions: “How does an intensive, content-based professional development program affect science teachers’ learning? How does this, in turn, affect their classroom practice?” There are a number of sub-questions that arise from these central questions, in the context of the Laboratory Science Teacher Professional Development (LSTPD) Program.

- 1) What is the impact of LSTPD on professional growth, as measured by the participant, in terms of their learning and pedagogical content knowledge?
- 2) To what extent do science teachers in the program view professional development opportunities as enhancing their professional experience and expertise?
 - a. What is quality professional development in science, and how does that professional development meet the needs of these teachers?

- b. What are the teachers' views of the Laboratory Science Teacher Professional Development program?
 - c. How does district-mandated professional development compare to the Laboratory Science Teacher Professional Development experience?
- 3) How does the science teachers' view of classroom practice change after exposure to the Laboratory Science Teacher Professional Development program?
- a. Do teachers anticipate changing their classroom habits, their ideas about teaching science, or some combination of these?
 - b. How do their views of teaching as a profession and learning as a process change due to Laboratory Science Teacher Professional Development?

Significance of the Study

There are a number of significant aspects to this study. First, there is an established body of literature focused on both the need for professional development in science teaching, and also what that professional development experience might look like. This study contributes to both of these areas of scholarship. In the literature review, I provide a historical overview of science education and professional development. I then explore research on teacher learning and pedagogical content knowledge and apply them to the design of professional development. In doing so, I address what the key features of this professional development should be, and provide example programs where these features guided the design of the program. Finally, I examine the research on professional development and changes in classroom practice. Although there are many

strong science programs appearing around the United States, in my research none are as extensive or long-term as the Laboratory Science Teacher Professional Development Program, which asks teachers to commit four to eight weeks of their summer for three consecutive summers. This program is situated in an understanding of what teachers need to be successful, how they learn, and how to best offer continual support.

Second, the studies reported in Chapter Two were conducted by education researchers with specific frameworks for what secondary science teaching is, and what it should be, but whom, by large, are not practicing secondary science teachers. While I embrace the importance of research by faculty and outside organizations, I believe it will be valuable for a practicing secondary science teacher to study a science professional development program. The lens through which I view my profession and the kind of growth that best supports my colleagues and me is somewhat different than an outsider looking in, trying to capture the full picture. I live the full picture.

Limitations of the Study

I believe that my study will contribute to the larger body of research about the importance of professional development, how that professional development impacts teachers' learning, and how these teachers will make changes to their own practice. That being said, there are some limitations. This inquiry was limited to secondary science teachers selected for participation in the Laboratory Science Teacher Professional Development Program at the Lawrence Berkeley Laboratory in Berkeley, California. These teachers are highly motivated and have returned to the lab for a second or third summer of research. They volunteered to participate in the study, demonstrating their willingness to expend time and energy in improving their own content awareness and in

reflecting on practice. The goal of this study was not to replicate results of previous studies, nor was it to compare this program to other professional development programs. In keeping with the structure of any case study, this research is bounded by the context in which it was conducted. Additionally, I was a participant in the LSTPD program, as well as in the study. To legitimize the data, I will connect my assertions with the broader theoretical understandings on professional development and teacher learning. The results of this study are limited in that:

1. The findings are subject to interpretation.
2. Some questions may have gone unasked by the researcher.
3. Participants may not have expressed some thoughts due to time constraints.
4. Participants reported their own perceptions of how the program influenced practice. Actual pedagogical change may or may not have occurred (Hueni, 1999).

Summary

In this chapter, I provided an overview of the study, and its purpose, my personal biography, the research questions, and the significance and limitations of my research. The main purpose of the study is to examine the role that a professional development program, designed to revitalize the research interests of science teachers and improve their content knowledge and scientific skills, had on science teachers' learning. The central research questions are, "How does an intensive, content-based professional development program affect science teachers' learning? How does this, in turn, affect their classroom practice?" Sub-questions include: What is the impact of LSTPD on professional growth, as measured by the participant, in terms of their learning and

pedagogical content knowledge? To what extent do science teachers in the program view professional development opportunities as enhancing their professional experience and expertise? What is quality professional development in science, and how does that professional development meet the needs of these teachers? How does the science teachers' view of classroom practice change after exposure to the Laboratory Science Teacher Professional Development program?

Given that I am a participant in the study, as well as the research, my personal biography is uniquely important in describing my history with professional development, and suggesting why I chose to examine it further. Limitations in the study are due to the fact that it is bounded by context, the participants are self-selected, and the researcher is also a participant. This is also significant, in that this study gives voice to the participants, both in how the data are portrayed in Chapter Four, and how the data are analyzed by the researcher-participant in Chapter Five.

In Chapter Two, I review literature related to the study; specifically, I include a historical overview of science education and professional development, research on teacher learning and pedagogical content knowledge, what the key features of this professional development should be, and changes in classroom practice. In Chapter Three, I review the design and methodology guiding the study. This research employs case study design and constructivist theory to guide practical and theoretical decision-making. A mixed-methodological approach will be described. In Chapter Four, I present data and allow the participants to "tell the story" of their experience. In Chapter Five, I summarize the findings, make connections to the literature, and provide implications for further study.

Chapter 2: Review of Literature

“An accomplished teacher is a member of a professional community who is ready, willing, and able to teach and to learn from his or her teaching experiences. Thus, the elements of the theory are: Ready (possessing vision), Willing (having motivation), Able (both knowing and being able ‘to do’), Reflective (learning from experience), and Communal (acting as a member of a professional community). Each of the dimensions entails an aspect of personal/ professional development, and can connect with portions of a curriculum of teacher preparation or professional development” (Shulman & Shulman, 2004).

Overview

Before embarking on a review of literature related to teacher learning, professional development, and classroom practice, I provide a discussion of science education history in an effort to make clear what brought science educators to the current reform standards and curricula they are asked to enact. I then examine each research sub-question in an effort to more fully understand the literature related to the central research questions: “How does an intensive, content-based professional development program affect science teachers’ learning? How does this, in turn, affect their classroom practice?”

Historical Context of Science Education in the Twentieth Century

The birth of the twentieth century brought with it many new challenges in educating America’s youth. For the better part of the early 1900s, a progressive

movement in education emerged (DeBoer, 1991, p. 85-86). Its focus was on the child, and how science might have a real impact on the child's social development. Science should play a meaningful role, rather than its previous, more traditional role (teaching memorized facts with out any greater social relevance). Science-in-everyday-life was an important thrust in curricular materials, and texts included explanations of central heating, refrigeration, and automobiles (Atkin & Black, 2007, p. 789). For the first time, a sequence of courses emerged (namely biology, chemistry, and physics), and other sciences were labeled as electives (zoology, health, agriculture). A general science course emerged that showed connections between all science courses. Importance was placed on laboratory experience, although many leaders disagreed on how the laboratory should be used. It was also the beginning of the standardized testing movement.

The United States' involvement in World War II had a significant impact on science education. Four major effects were seen: (1) a nation at war required tremendous industrial and agricultural production; (2) enlistment and draft testing demonstrated that many recruits were deficient in basic literacy and quantitative reasoning skills; (3) tremendous shortages in personnel in technical fields were evidenced after the war, requiring training of a new generation of technologically literate individuals; and (4) the war demonstrated the importance of mathematics, technology, and science in conducting successful military efforts, and maintaining the country's stability post-war (i.e. competition with the Soviet Union) (DeBoer, 1991, p. 128).

To compound post-World War II science concerns were the problems facing the teaching community. Teaching personnel were also in short supply. Teacher pay was low and training was substandard. In response, AAAS surveyed 567 scientists as part of

President's Scientific Research Board, to determine the needs in science education: better pay, more rigorous training, and more emphasis on practical applications. "Teachers need to learn from first-hand observations the applications being made of science and mathematics in manufacturing, agriculture, mining, medicine, research, and the like" (President's Scientific Research Board, 1947, Vol 4, p. 86, as quoted in DeBoer, 1991, p. 132). As a result, the 1950's saw partnerships between scientists, the National Science Foundation, and public education. A curricular reform movement took shape that required greater rigor, and encouraged students to think and act like scientists. Examples of new physics curricula emerged from the Massachusetts Institute of Technology and Harvard University that were based on contemporary university research rather than purely practical work like understanding automobile engines (Atkin & Black, 2007).

The 1960s and 1970s are a unique era in the history of science education. This was a particularly significant time of the Cold War; policymakers and scientists alike were competing with advancements in understanding and technological development with the Soviet Union. Both groups needed a steady flow of trained scientists. The scientific community was concerned because the public viewed their work as technology-based rather than as basic knowledge production. Waning student interest and enrollment in science as the United States entered the 1960s prompted educators to question the role of science in current society. Many earlier projects "ignored one of the more important reasons for teaching science in any culture at any time, namely, to provide individuals with knowledge and skills that would help them live intelligent lives in the culture in which they found themselves" (DeBoer, 1991, p. 172). Scientists felt the public needed broader, deeper understanding of how science was done. In 1964, the National Science

Foundation sponsored a variety of K-12 curriculum development projects to provide early exposure to “authentic” science. Students learned science by reasoning from direct observation of natural phenomena, with the greatest emphasis on general learning (making observations, measuring, articulating hypotheses, designing and running experiments). By 1977, 60% of US school districts were using an NSF sponsored curriculum (Duschl, Schweingruber, & Shouse, 2007). There were issues in implementing this reform curriculum, including the cost, and political concerns, in that the content was unfamiliar to many and sometimes disturbing to parents (like evolution). Developers also underestimated the: (1) influence students’ prior knowledge had on learning; (2) impact of students’ and teachers’ naïve ideas about inquiry; (3) challenge of improving curriculum on a large scale (Duschl, Schweingruber, & Shouse, 2007).

In 1983, the National Commission for Excellence in Education, consisting of university presidents, professors, and K-12 educators, published their report on K-12 education in *A Nation at Risk*. They claimed that US schools, “lost sight of the high expectations and disciplined effort needed to attain the necessary goals of education” (Duschl, Schweingruber, & Shouse, 2007, p. 15). Policymakers were concerned about how the dwindling quality of American education, specifically science education would impact the economy and standard of living. They urged for more science requirements in schools, and more opportunities to learning science (after school, summer). By the 1990s, standards for content, instruction, assessment and professional development were provided as a framework for offering a sufficient level of knowledge and skills. In terms of subject matter, *Benchmarks for Science Literacy* and the *National Science Education Standards* provided guidance for curriculum development. These curricular efforts also

led to state-level assessments. This focused effort allowed for greater funding from federal agencies and research groups, like NSF.

In 2008, there is still a long way to go. Some of the factors that explain the limited impact of reform efforts are: (1) political and technical aspects on implementation, (2) insufficient teacher preparation and professional development, (3) discontinuous streams of reform, (4) mismatches between goals of the initiatives and assessments, and (5) insufficient and inequitable material resources devoted to education and reform (Duschl, Schweingruber, & Shouse, 2007, p. 17). No Child Left Behind (NCLB) broadened the federal role in education reform. Schools now report test scores across demographic groups. Science itself is changing. The three decades leading up to the 1990s had a similar battle cry as the progressive era at the turn of the century – how can educators integrate science into human relationships and actions and ultimately meet students’ interests (DeBoer, 1991, p. 173)? Educators questioned the meaning of a scientifically literate public, and realized the interconnectedness of science, technology, and society. New fields of science are emerging (e.g., nanoscience, computational biology), and the lines across them blur. The current era is marked by digital technology that does not connect as easily to in class science investigation. Whereas students could discuss rotation, electricity and other physical science concepts by viewing a turntable in the past, they cannot simply open their iPod and gain the same understanding (Duschl, Schweingruber, & Shouse, 2007, p. 19). There are also new understandings of how people learn – even young children have ideas about the natural world – and more specifically, how they learn about science – through television, internet, museums, and national parks.

There is still a level of disagreement, however, over what it means to be scientifically literate (DeBoer, 2000). DeBoer (2000) suggests that an understanding of the history of science education in the United States may provide a framework for defining scientific literacy in the present. He provides nine key features from the history of science education, and their implication for current science reforms:

(1) Teaching and Learning About Science as a Cultural Force in the Modern World (...proponents of science in the curriculum have argued that a well-informed, cultured, literate individual must know something about the way the natural world works, about the scientific way of thinking, and about the effect of science on society...).

(2) Preparation for the World of Work (science classes enhance students' long term employment prospects in a world where science and technology play such a large role);

(3) Teaching and Learning About Science That Has Direct Application to Everyday Living (...an understanding of such things as light, electricity, heat, evaporation and condensation, plant nutrition, human anatomy and physiology, health and disease, and photosynthesis, all contribute to a more informed and intelligent experience with the natural world...).

(4) Teaching Students to be Informed Citizens (...science instruction helps develop informed citizens who are prepared to deal intelligently with science-related social issues, to vote responsibly, and to influence, where appropriate, policies related to the impact of science on society...).

(5) Learning About Science as a Particular Way of Examining the Natural World (...the validity of data, the nature of evidence, objectivity and bias, tentativeness and uncertainty, and assumptions of regularity and unity in the natural world are all important concepts for students to be aware of...).

(6) Understanding Reports and Discussions of Science That Appear in the Popular Media (...science education should develop citizens who are able to critically follow reports and discussions about science that appear in the media and who can take part in conversations about science and science-related issues that are part of their daily experience...).

(7) Learning About Science for its Aesthetic Appeal (...science instruction should develop an appreciation for the great variety of plants and animals, the fascinating intricacies of animal behavior, the natural beauty found in geologic formations, and the mysteries held by sea and sky...).

(8) Preparing Citizens Who are Sympathetic to Science (...this goal is based on the assumption that science is, on balance, a force for good and that an awareness of science and the methods of science will lead to an appreciation of science on the part of students...).

(9) Understanding the Nature and Importance of Technology and the Relationship Between Technology and Science (...technology is a legitimate part of the science curriculum because the subject matter deals with the physical world, technological design depends on scientific principles and parallels the methods of scientific inquiry, and the study of technology has the potential to be more

immediately interesting and motivating to students since it deals with concrete objects from their everyday experience...) (DeBoer, 2000, pp. 591-593).

Professional Development

Studies dating back to the 1970s show the link between teacher development and educational change, yet little is understood about the evolution of the teacher (Fullan, 1993). In keeping with the call of current science reform documents, research into teacher learning and change is essential in creating an understanding of how to better prepare and maintain scientifically literate professionals and impact classroom practices. I will present emergent literature on the science teacher as learner, including insight into pedagogical content knowledge as a framework for understanding teachers' personal and professional views. I will also review research related to the role of professional development in meeting the needs of science teachers; specifically, what research defines as the facets of good professional development, and provide examples of such. Finally, I will connect teacher professional development to changes in classroom practice by first examining teacher change, and more specifically, the impact of professional development on teachers' habits, views, and their students' learning.

Teacher Learning and Pedagogical Content Knowledge

The National Science Education Standards (NRC, 1996) formally called for professional development to include experiences that engage prospective and practicing teachers in active learning that builds their knowledge, understanding, and ability (p. 56). Since that time, a number of studies have reviewed how professional development impacts teacher learning (Ball & Cohen, 1999; Borko, 2004; Fishman et al., 2002;

Hewson, 2007; Kwakman, 2003; Loughran, 2007; Pohland & Bova, 2000). It should be noted that teachers in various stages of their career may require different types of learning. Teachers in their first five years are beginning to shift to constructivist teaching and learning through reflection, and beginning to develop PCK (Loughran, 2007). They often struggle to do this and meet the day-to-day concerns/expectations of being a teacher, largely because of the differences between teaching for understanding and teaching to pass an exam. Those that are able to be reflective about their practice begin to understand the serendipitous nature of learning, become risk-takers with approaches, and develop more coherent views of the courses they teach. What beginning science teachers as learners need is genuine support and guidance so they can learn to “frame and name the nature of their concerns in order to actively decide what they need personally to pursue to enhance their own learning about teaching and learning in science” (Loughran, 2007, p. 1051).

Experienced science teachers as learners need encouragement to make the “tacit explicit” (Loughran, 2007). One way to achieve this is through work with science education researchers through graduate course enrollment. Teachers learn educational theories and practices and can more easily articulate their understandings about teaching and learning. Another way to encourage teacher learning is through practice. Teachers must accept that teaching is problematic – a series of dilemmas (managed, not solved), whereby they are constantly developing and understanding the tensions, frustrations, and concerns associated with their roles as teachers.

The notion of teacher learning is inextricably connected to concerns over practice. Wallace (2003) articulated three conceptual themes:

(a) that learning about teaching is situated, and as a consequence, the development of teachers' understanding and knowledge requires a focus on authentic activities; (b) that learning about teaching is social and that "creating rich opportunities for diverse groups of teachers to participate in, and to shape, discourse communities" is critical (p. 10); and (c) that learning about teaching is distributed, and, hence, collaboration is central to change (As quoted in Loughran, 2007, p . 159).

Most professional development opportunities focus on providing teachers with strategies and activities that they can use in the classroom (Ball & Cohen, 1999; Little, 1993). The argument has been made, however, that teachers need to become serious learners in and around their craft (Jeanpierre et al., 2004, Garet et al., 2001; Loucks-Horsley et al., 2003), and professional development should provide these opportunities for intellectual professional growth. Part of the difficulty with professional development is that, "although the projects are sympathetic to the work of the science teachers, and the researchers are concerned for the development of quality in science teaching and learning, the teachers themselves have not necessarily been the initiators or sustainers of the research effort" (Loughran, 2007, p. 1054-1055). As described by Ball and Cohen (1999), successfully designed professional development emphasizes three "cornerstones of education":

- 1) what needs to be learned (content); 2) the nature of that content and what that implies about how it might be learned (theories of learning); 3) curriculum and pedagogy (with what material and in what ways the learners can be helped to learn that content, given who they are and the nature of what there is to be learned and theories of how it is best learned).

For teachers to learn, the context of practice and situated experience is essential (Ball & Cohen, 1999; Putnam & Borko, 2000). As Ball and Cohen (1999) note, if we expect teachers to construct knowledge of practice, this knowledge should be acquired in practice; to do otherwise would be expecting someone to learn to swim on the sidewalk. The questions for developers of professional growth experiences are what knowledge should teachers be learning, and what kind of practice will facilitate this learning?

According to Ball and Cohen (1999), professional development should center on learning things relevant to performance. It should give teachers experience with tasks and ways of thinking fundamental to their practice. “[Science] teaching has suffered because science has been so frequently presented just as so much ready-made knowledge, so much subject-matter of fact and law, rather than as the effective method of inquiry into any subject matter” (Dewey, 1910). Second, it should cultivate knowledge and skills that enable teachers to facilitate learning with students. A recent study by Jeanpierre, Oberhauser, & Freeman (2005) suggests that increasing teachers’ science content knowledge and then asking them to apply that through experiences supports teacher learning and positive classroom change. Finally, professional development should encourage investigation, analysis and criticism of professional work through discourse and communities of practice (Ball & Cohen, 1999; Butler et al., 2004). Discussion provides a vehicle for analysis, criticism, and communication on practice, and attempts to build collegiality within the profession (Ball & Cohen, 1999). Stated differently, discourse facilitates learning, which is linked with the process of developing identity – one moves from being a peripheral participant to full participation in a given community (Butler et al., 2004).

Content and Practice

One important call within the science teaching community is for professional development to focus on content. By design, professional development often focuses on methods of practice. While the importance of this cannot be overstated, it is equally important to recognize the need for content growth opportunities. For example, science teachers can be at a great disadvantage if they do not follow advancements and changes in the field, because these changes often impact the way a concept is perceived for students. Loucks-Horsley and Matsumoto (1999) suggest that teacher expertise and knowledge of subject matter had a significant impact on students' opportunities to learn and understand science. For this reason, professional development should offer teachers greater exposure to content, and the chance to interact with content in new ways. While much literature on professional development speaks solely of content in terms of pedagogical linkages (Radford, 1998), it is important for teachers to work with content for the sheer experience of being a practitioner in that field. Part of knowing how to teach science is knowing what it means to do science (Garet et al., 2001). Ball and Cohen's (1999) assertion that professional education requires professional experience and performance with tasks fundamental to practice, supports this claim. In the context of this study, in order to understand science content and acquire knowledge, teachers must engage in scientific work. More about the importance of content will be discussed when examining the design of professional development.

Knowledge and Skills

Teaching science in an age of reform means that teachers must have the ability to communicate basic knowledge, and also develop advanced thinking and problem-solving

skills in their students (Garet et al., 2001; Loucks-Horsley, Hewson, Love, & Stiles, 2003). To enhance the knowledge and skills of students, we must also enhance the knowledge and skills of teachers. By engaging teachers in “active work, and by fostering a coherent set of learning experiences, professional development is likely to enhance the knowledge and skills of participating teachers and improve their classroom teaching practice” (Birman et al., 2000). Professional development should engage teachers in the kinds of investigation and experimentation that prepare them for the multiple reform agendas they face (Little, 1993). These include reforms to subject matter teaching; those centered on problems of equity and diversity; reforms on the nature, extent, and uses of assessment; those in the social organization of schooling; and reforms to the professionalization of teaching (Little, 1993).

Gess-Newsome (2001, p. 91) stated that, “As a professional, a teacher is both a user and a creator of knowledge when making planned and spontaneous instruction decisions.” It is therefore essential that teachers engage in discourse about their knowledge and belief systems, and are encouraged to work in a framework of continuous self-reflection and professional growth. To do this, certain key characteristics of professional development must be integrated into the backdrop of all professional development activities. As a result of a thorough analysis of learning principles and the current paradigm shift in professional development, Hawley and Valli (1999) asserted eight design principles related to a New Consensus Model of Professional Development. First, the professional development must be driven by analysis of the differences between goals and standards for student learning and those for student performance. Second, it should involve teachers in the identification of learning needs. Third, it should be school

based. Fourth, it should also provide learning opportunities related to individual needs and organized around collaborative problem solving. Fifth, professional development must be sustained over time, and supported by external sources. Currently, professional development is short and fragmented (Gess-Newsome, 2001; Lord, 1994). Sixth, Hawley and Valli (1999) suggest it should incorporate evaluation of multiple sources of information on implementing lessons learned through professional development. Seventh, it should provide for theoretical understanding of knowledge and skills. Finally, it should allow for change in order to best address impediments to and facilitators of student learning.

Collaboration

The concept of communities of practice (COP) links learning with the development of identity, and the movement from peripheral participation in a community (i.e., a school) to full participation (Butler et al., 2004) and is often applied to the enculturation of pre-service teachers as they shape their identities. Butler and colleagues (2004) invited teachers within a school district to participate in a learning community with the common goal of trying an instructional innovation called “strategic content learning” (SCL). Strategic content learning referred to engaging students using interactive discussion which then allowed the teachers to be more reflective practitioners. Groups consisted of district personnel, teachers, and researchers. The goal of the community was to promote independent, strategic, and problem solving approaches to learning by students who were struggling. Butler et al. (2004) found that when COP’s are applied to professional development, teachers are allowed to develop “intellectual groups who share goals/purposes and engage in planning, enacting, and reflecting. In

these communities, learning proceeds from action, expertise is distributed, and knowledge is socially constructed” (Perry et al., 1999 as quoted in Butler et al., 2004). Applying a COP framework has advanced understanding of teacher learning in two ways. A COP perspective “foregrounds the influence of history, society, and community in shaping teacher learning” (Butler et al., 2004). It has also allowed for analysis of how learning between and among teachers is “grounded in reflection on action” (Butler et al., 2004).

Teachers often find themselves isolated in their practice. They are given few opportunities to collaborate with their colleagues, and when they do, they are often working on a particular student issue, like an intervention plan, rather than something more reflective of practice (Hawley & Valli, 1999). To decrease teacher isolation, Hawley and Valli (1999) argue for learning opportunities organized around collaborative problem solving professional development.

The perception of teachers and teaching has changed since the 1980s. Loucks-Horsley (1995) cites two factors that contributed to the change in teaching and teachers from generic transmitters of rote knowledge to competent, respected professionals: (1) teachers are required to be highly knowledgeable in their content field, and (2) it is recognized that teachers possess special knowledge and abilities that enable them to connect content and pedagogy. Shulman (1987) refers to this special knowledge as pedagogical content knowledge. Opening a window into how teachers make sense of new knowledge – their learning styles and perceptions of change in their practice – could prove a valuable tool in organizing professional development models.

Pedagogical Content Knowledge

Pedagogical content knowledge (PCK) is defined as:

The special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding... Pedagogical content knowledge... identifies the distinctive bodies of knowledge for teaching.

Pedagogical content knowledge is the category most likely to distinguish the understanding of the content specialist from that of the pedagogue (Shulman, 1987, p.8).

Shulman's (1987) conception of PCK was placed as one of seven knowledge base categories of teaching, including: content knowledge, general pedagogical knowledge, curricular knowledge, knowledge of learners, knowledge of educational contexts, and knowledge of the philosophical and historical aims of education. PCK, however, is specific to a teacher's knowledge of student alternative conceptions and difficulties, and how to represent subject matter to diverse interests and abilities. The National Science Education Standards (NRC, 1996) acknowledge PCK as "special understandings and abilities that integrate teachers' knowledge of science content, curriculum, learning, teaching and students," which allows science teachers to, "tailor learning situations to the needs of individuals and groups" (p. 62). The working definition represented in this study is: PCK represents knowledge and its applications that are central to science teachers' work and that would not typically be held by scientists or pedagogues in other disciplines; it allows the science teacher to facilitate and assess instruction through inquiry and other instructional methods in any teaching situation. The recognition of

PCK in the late 1980s gave credence to the argument that teaching science could in fact be distinguished from teaching other subjects, or being a scientist.

Many views exist to explain PCK (van Driel, Verloop, and de Vos, 1998), but the key in Shulman's conception is the interplay between subject matter and understanding specific learning difficulties and student conceptions. "As many of the latter have been revealed by research on student learning, submitting PCK to scientific inquiry offers an opportunity to link research on teaching with research on learning" (van Driel, Verloop, & de Vos, 1998). Two models of PCK, the integrative model and the transformative model, were presented by Gess-Newsome (1999). They are distinguished in Table 1. The integrative model requires teachers to merge their separately held understanding of subject matter knowledge, pedagogy, and context while the transformative model suggests that these knowledge domains are synthesized as one.

Table 1: Overview of Integrative and Transformative Models of Teacher Knowledge (Gess-Newsome, 1999, p. 13)

	Integrative Model	Transformative Model
Knowledge domains	Knowledge of subject matter, pedagogy, and context are developed separately and integrated in the act of teaching. Each knowledge base must be well structured and easily accessible.	Knowledge of subject matter, pedagogy, and context, whether developed separately or integratively, are transformed into PCK, the knowledge based used for teaching. PCK must be well structured and easily accessible.
Teaching Expertise	Teachers are fluid in the active integration of knowledge bases for each topic taught.	Teachers possess PCK for all topics taught.
Implications for Teacher Preparation	Knowledge bases can be taught separate or integrated. Integration skills must be fostered. Teaching experience and reflection reinforces the development, selection, integration and use of the knowledge bases.	Knowledge bases are best taught in an integrated fashion. Teaching experience reinforces the development, selection, and use of PCK.
Implications for Research	Identify teacher preparation programs that are effective. How can transfer and integration of knowledge best be fostered?	Identify exemplars of PCK and their conditions for use. How can these examples and selection criteria best be taught?

Beginning teachers do not have the same level of PCK as experienced teachers; it is often associated with experiential knowledge which is developed through classroom experience (Gess-Newsome, 1999; NRC, 1996; van Driel et al., 2001). A study by Gess-Newsom and Lederman (1993, as quoted in van Driel, Verloop, & de Vos, 1998) indicated that pre-service biology teachers relied on their college science coursework to provide structure in teaching subject matter. Their skills developed over the course of their pre-service year, but the authors suggested that, “until a teacher has gained

experience and mastered basic classroom skills, it may be unrealistic to expect a readily accessible and useful translation of subject-matter knowledge into classroom practice” (van Driel, Verloop, & de Vos, 1998). This suggests that the more opportunities teachers have to navigate the complexity of the classroom, the more effectively they can develop and deploy their PCK. Expert teachers develop their PCK through “trial and error in teaching situations, continual thoughtful reflection, interaction with peers, and much repetition of teaching science content” (NRC, 1996, p.67). This suggests that collaborative work between beginning teachers and experienced teachers, specifically in professional development, could be effective in fostering PCK.

Experienced science teachers “grow” their PCK from a variety of sources, including their own practice or other school-oriented activities, like in-service courses. Studies on science teachers’ PCK indicate that thorough subject matter understanding is a prerequisite, preceding the development of PCK. This has been demonstrated through studies on the effect of teaching unfamiliar topics (van Driel, Verloop, & de Vos, 1998). When teaching a topic outside of their certification area, experienced teachers are sustained by their general pedagogical knowledge, while their PCK is limited. This occurs because of their unfamiliarity with the content, and hence, their unfamiliarity with student conceptions of that content. These teachers quickly learn, however, how to adequately instruct the new content, while relying on their pedagogy knowledge to maintain the flow of the class.

PCK can be particularly difficult to research, in that it may not be evident to an observer in one lesson. Hence, teachers need to articulate their PCK. This poses a unique problem because teachers generally do not possess the language or training

necessary to make explicit their PCK. “In addition, for science teachers there is little opportunity, time, expectation, or obvious reason to engage in discussions helping them to develop tacit knowledge of their professional experience into explicit, articulable forms to share across the profession” (Loughran, M. & Berry, A., 2004).

Professional Development and the Professional Experiences of Teachers

Educational researchers have, over the last fifteen years, studied professional development both systematically and programmatically. There is much overlap in what researchers believe to be characteristics of good professional development, or professional development that shapes the teachers’ understandings and beliefs. The challenge lies in constructing

a comprehensive perspective on the relations between professional development and the improvement of teaching and learning, in a system in which professional development, like other education, has been superficial and fragmented; the commitment to and belief in serious professional development is quite limited, and theories of professional learning have been implicit and undeveloped (Ball & Cohen, 1999, p. 5).

Ball and Cohen (1999) argue that there are no carefully constructed or empirically based theories guiding teacher professional development, and as a result, school systems continue to emphasize one-shot workshops rather than implementing sustained programs. They assert that professional development in most forms tends to be fragmented, intellectually superficial, and does not take into account how teachers learn (Ball & Cohen 1999). They assert, and I agree, that teacher learning theory is essential in framing professional development. Given this theoretical framework, it becomes necessary to

examine how one might situate professional development experiences. Knowledge and learning are always situated – the question becomes in what context to situate them (Putnam & Borko, 2000).

Professional Development – Components and Design

The American Association for the Advancement of Science (AAAS) published four recommendations for continuing professional development for science educators in its 1998 text *Blueprints* (AAAS, 1998). They identify the most important reason for professional development as allowing teachers to recognize the special expertise related to their work – their specialized knowledge that gives them authority over curricular choices. The second reason is that pre-service education is neither long enough, nor intense enough for teachers to master all of the skills they need. Third, “as knowledge in the fields of both science and teaching continues to expand, and as our society and its demands continue to change, teachers themselves must grow and develop” (AAAS, 1998). Finally, teachers who engage in long-term professional development build a wider network of peers, which provides a sense of community and improves teaching quality.

The National Research Council published a set of professional development standards in 1996 entitled the *National Science Education Standards* (NSES) (National Research Council, 1996). These include recommendations for teachers of science to learn science content through inquiry, to integrate knowledge of science, learning and pedagogy, to build understanding as a lifelong learner, and for professional development opportunities to be coherent and integrated (NRC 1996).

Jorgensen (2001) states that, “If professional development is the critical factor in promoting systemic change for practicing teachers, supervisors, administrators, and ultimately students, as suggested by the NSES, what model or models for professional development will likely produce the greatest improvement” (p. 124)? In addressing this question, it is important to note that my focus is on how professional development centered on an understanding of teacher learning changes teacher practice – in essence, I would answer Jorgensen’s question by looking at improvement in how and what the teacher learns. I believe that if the basis of any professional development endeavor is enhancing teacher learning and expertise in both content and pedagogy, then teachers will be better prepared to meet the challenging standards of our current science education reform model (Loucks-Horsley & Matsumoto, 1999). I am not reporting on student achievement because it is recognized as being influenced by a number of factors that I perceive would be difficult to capture in this study. Loucks-Horsley and Matsumoto (1999) suggest that connecting professional development to student learning can be complex because one would have to capture the various contributions that each factor makes to the desired outcome.

Sample Professional Development Programs

Because inquiry is such a prevalent term in the National Science Standards (NRC, 1996), it is appropriate that teachers would receive professional development in inquiry models of teaching. There are current professional development programs cited in the literature that focus on inquiry based approaches to science teaching and learning. Most have a content focus and possess many of the key features of professional development discussed earlier.

There are examples of programs currently in place that focus science teachers on both content and pedagogy. The Texas Regional Collaboratives (TRC) for Excellence in Science Teaching is a program for Texas science teachers considered an effective professional development model according to the standards set by Meyer and Barufaldi (2003). Mayer and Barufaldi draw from Loucks-Horsley's (2003) description of effective professional development which is described later. This program is supported at three levels: the university level, the state office level, and the collaborative level. Teachers work on collaborative projects in the areas of scientific literacy, technology, standards, equity, assessment, and constructivism. Each region in Texas has its own unique agenda that is guided by the teacher and student populations in those areas. The goal, regardless, is the increase of teacher content knowledge and pedagogical content knowledge. Additionally, the model emphasizes the importance of raising student achievement in science. Teachers work in a two-week institute with university professors on inquiry and are trained in using the inquiry method. They are asked to perform an inquiry-based investigation, and ultimately will use this model in their own classrooms. From there, teachers work in learning communities and statewide committees, where they are able to take on leadership roles.

These traits can be mapped to Loucks-Horsley et. al's (2003) Principles of Effective Professional Development for Science Teachers. It is suggested that professional development be well defined, which the Texas Regional Collaboratives (TRC) hopes to achieve through its systemic threads. Loucks-Horsley also recommends that teachers build their knowledge and skills, for which the TRC has developed academies of learning. Professional development should also provide models for

teachers to use in the classroom; the TRC is designed in a way that demonstrates how teachers would teach their students. Teachers are supposed to take on roles of leadership, which was mentioned earlier. The TRC connects science teachers with experts in science and science education. Finally, professional development should be continually assessed, which the TRC does through a pre-and post-assessment for each year (Meyer & Barufaldi, 2003).

Two programs in Virginia have opened up opportunities for teachers to receive training and collaborative support in inquiry models of teaching. Both projects are funded through federal grants for science professional development, but run at local colleges (Alouf & Bentley, 2003). The Sweet Briar Professional Development Project started in 1999 by conducting summer workshops for chemistry teachers in grades 6-12, but eventually added all disciplines and all grade levels within two years of the project's inception. Teachers were exposed to modules with a broad range of inquiry activities. After their participation, teachers returned to the college often for one-day academies where they "discussed inquiry in their classrooms and investigated more activities for classroom implementation" (Alouf & Bentley, 2003). The Hollins University Professional Development Project is geared for elementary science teachers and begins with a two-week summer institute, where intensive daily investigation and collaboration take place, and a workshop day in the fall, is also held, designed for debriefing. Teachers work with Virginia's standards for learning and are visited by science faculty and Natural History Museum scientists to conduct inquiry lessons, integrated instruction, and differentiated instruction periodically throughout the school year. A communication website is then provided for ongoing communications and resources.

The ENVISION project is run through Purdue University, but is available to middle-level environmental science teachers from around the country. The focus is learning science through the investigation of local environmental issues and demonstrating appropriate research techniques (Shepardson et al., 2003). Teachers spend several weeks in the summer in a residential program, where teachers live on a campus together, and work in teams to conduct their own research. Teachers construct their own meanings of inquiry, what it means in their classroom, and learn to work together to communicate findings. In addition to adding to pedagogy, this program facilitates discussion about content; as teams are assigned a problem, and then asked to draft a proposal for the best way to solve it, using inquiry methods. The audience is the local city council, or other interest groups, which makes the research relevant to the community. Teachers collect data in the field, analyze that data, and at the end of the program, present that data to their colleagues. Teachers learn science in context and learn to link that context to their own classroom instruction.

A key feature of all of these programs is the inquiry format. Inquiry refers to “the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work” (National Research Council, 1996). All are taught with inquiry at the center, and both projects distinguished between hands-on learning and inquiry learning. Teachers were asked to develop open-ended investigations rather than the prescribed science so often found in schools. Teachers were also learning to work within the standards, but not to see them as oppressive. The programs allow teachers to investigate inquiry – a method often thought to be incongruent with standards based teaching and assessment.

Teacher Change – Changes in Inquiry and Changes in Practice

The concept of change can be simply stated as something transitioning from being the same to being different. It is not defining change that is difficult; it is the reality of change. Teachers feel excitement, trepidation, anticipation, or even resentment at the possibility of change. Often the hesitation stems more from the process than the product – teachers want to help children learn, and if change is intended to benefit children, it gains momentum in the teaching community. Implementation, however, can be difficult, and one significant reason why it is so difficult, is the ineffective or inadequate professional development provided to facilitate change.

Change, while challenging, is essential to renewing our vitality. Hueni (1999) noted that change is associated with teachers who develop habits of inquiry – they continually and actively construct their view of education, are lifelong learners, and effectively transmit these expectations to their students.

Teacher change requires that teachers be cognizant of their own needs, their models of practice, and their value system (Fullan, 1993). Teachers are asked to change for a variety of reasons, including curricular changes, assessments, and state or federal mandates. Professional development activities should be used to not only introduce changes but also to allow teachers to make sense of change, and to assist them in integrating new knowledge into previous frameworks. Teachers who confront change and learn from it are crucial in the evolution of society (Fullan, 1993).

Teachers are more likely to change behavior and integrate new ideas when certain learning criteria are met. Stallings (1989) identified four cornerstones in her teacher change model: (1) learn by doing, try, evaluate, modify, try again; (2) link prior

knowledge to new information; (3) learn by reflecting and problem solving; and (4) learn in a supportive environment where problems and successes are shared.

Teacher change is facilitated by three factors: professional development, collaboration with colleagues, and time (Hueni, 1999). I see these as mutually necessary in helping teachers change and grow – professional development should be designed to encourage collaboration, and teachers should be given sufficient time for discourse and reflection. The question is then how to create professional development opportunities that provide for this.

The American Association for the Advancement of Science (AAAS) suggested in their 1998 publication *Blueprints* the following principles to guide the redesign of teachers' continuing education:

- Higher education and professional associations should strengthen their connections to professional development, providing greater coherence.
- An emphasis on science learning tied to local school context should replace the focus on general teaching skills.
- Activities should provide the curricular and practical skills for teachers to weave standards and benchmarks into an instructional sequence.
- Cadres of teachers should assume leadership responsibilities.
- Activities should promote learning for all school professionals, including administrators (AAAS, 1998).

Principles of Design: Change and Inquiry

Hawley and Valli (1999) reviewed research-based principles for teacher learning and the implications they had for professional development. They discuss five learning-centered principles reported by Alexander and Murphy (1998, reviewed in Hawley & Valli, 1999): (1) the knowledge base principle – one’s existing knowledge serves as a foundation for all future learning; (2) the strategic processing principle – the ability to reflect on and regulate one’s thoughts and behaviors; (3) the motivation/affect principle – motivational and affective factors (personal goals for example) play a role in the learning process; (4) the development principle – learning is unique for everyone and proceeds through complex stages, influenced by inherited, experiential, and environmental factors; and (5) the context principle – learning as a socially shared undertaking. Varied learning principles suggest that teachers and students learn in varied ways. Professional development can introduce teachers to research on learning and how to facilitate it best. They also suggest why professional development can be ineffective (Smylie & Conyers, 1991). The motivation principle, for example suggests that professional development should take into account the personal identities of teachers and the cultural contexts in which they work. To do this, professional developers must consider the context and critical issues facing the teachers engaged in a particular program when developing the program, implementing it, and ultimately supporting it (Loucks-Horsley, Love, Stiles, Mundry, & Hewson, 2003). Context could mean the learning standards in the school, the organizational culture, or available resources. Likewise, critical issues may include time, equity, and sustainability.

Professional development opportunities are rarely designed by teachers for teachers (Howe & Stubbs, 1996). In fact, much of the professional development in which teachers engage is “everything that a learning environment shouldn’t be – understaffed, non-sustained, imposed rather than owned and lacking intellectual coherence” (Miles, 1995 quoted in Howe & Stubbs, 1996, p. 168).

In the past, programs for professional development focused on the deficiencies of teaching rather than using competency-based approaches (Smylie & Conyers, 1991 quoted in Howe & Stubbs, 1996, p. 168; Clarke & Hollingsworth, 2002).

Professional development became a major enterprise in education during the post-depression era (Howey & Vaughan, 1983). At that time it was based on a training paradigm that implied a deficit in teacher skills and knowledge (Guskey, 1986). Most professional development consisted of “one-shot” workshops aimed at teacher mastery of prescribed skills and knowledge. Professional development attempts based on this deficit model have been criticized throughout the literature....The clear ineffectiveness of attempts to effect teacher change through professional development programs based on the deficit-training-mastery model has provided the impetus for much research related to the process of change and professional development in recent years. A significant outcome of this research has been the shift in focus from earlier conceptions of change as something that is done to teachers (that is, change as an event with teachers as relatively passive participants), to change as a complex process that involves learning (Fullan & Stiegelbauer, 1991; Guskey, 1986; Hall & Loucks, 1977; Johnson, 1989, 1993, 1996a, b; Teacher Professional Growth Consortium, 1994). The key shift is one of

agency: from programs that change teachers to teachers as active learners shaping their professional growth through reflective participation in professional development programs and in practice (Clarke & Hollingsworth, 2002, p. 948).

A more effective curricular model has been suggested by Howe and Stubbs (1996) and is informed by both constructivist (Piaget, 1955) and sociocultural theory (Vygotsky, 1986).

Constructivist theory is often applied to how students learn in a particular setting.

Constructivist approaches allow teachers to build on prior knowledge, assimilate and accommodate new information, invent rather than accumulate, and reflect and resolve cognitive conflict (Fosnot, 1989 as quoted in Howe & Stubbs, 1996; Kwakman, 2003). It is not often applied to how a teacher can construct new layers of knowledge through professional development. Sociocultural theory proposes that knowledge is bounded by specific contexts of social practice and focuses on social interactions as a primary source of knowledge.

Howe and Stubbs (1996) argue for a model of professional development based on the idea that knowledge is not transmitted directly from one person to another, but is actively constructed by the learner. They also argue the knowledge is bound to specific contexts of social practice and is always embedded in the social context shared with a group or community. Teachers gain experiences constructing knowledge of science and how to teach science, and develop professionally, personally, and socially. They implemented their model using a program called SCI-LINK, a teacher enhancement project for science teachers. The institute ran over two weeks on large university campuses, and was continued for three consecutive summers. Teachers worked to weave current environmental research into their existing curriculum. The participants

maintained communication through networks designed by the researchers, and were offered support in the form of one-day workshops throughout the school year. In the end, teachers spoke of increased self-confidence, development of new ideas and practices, and the development of previously unsuspected leadership abilities. Teachers noted, “We were treated as professionals,” and “We learned so much from each other” (Howe & Stubbs, 1996).

The transformational model of science teaching is closely associated with the goals of constructivism and sociocultural theory. Transformational learning “seeks to free the individual from the chains of bias through the process of perspective transformation; i.e., ‘the process of becoming critically aware of how and why our assumptions have come to constrain the way we perceive, understand, and feel about our world’” (Mezirow, 1991, p. 167 as quoted in Pohland & Bova, 2000, p. 139). “Genuine, deep, and lasting reform calls for the transformation of how teachers think about and teach science” (Parke & Coble, 1997). Transformational professional development has several goals for teachers: (1) they gain a clearer understanding of barriers to learning by challenging students’ prior conceptions; (2) challenge their beliefs about practice; (3) invite them to listen and reflect on current research literature; (4) assist them in the design of curriculum that aligns with their insights; (5) support them in practicing new ways of teaching (Parke & Coble, 1997).

Transformational learning implies that there will be some kind of change in the learner as an end-result. Clarke and Hollingsworth (2002) state that there are a number of alternative perspectives on the notion of “teacher change.” Teacher change can be seen as training (teachers are “changed”), adaptation (adapt practice to changed conditions),

personal development (improve or develop skills), local reform (reasons of personal growth), systemic restructuring (enact change policies of the system), growth and learning (teacher are learners in a learning community). These are not mutually exclusive, and are adaptable. The most important focus of teacher change for this study is on growth and learning.

According to Supovitz and Turner (2000) professional development is “most likely to be of high quality” if it includes the following components: (1) immerses participants in inquiry, (2) is intensive and sustained, (3) engages teachers in concrete teaching tasks, (4) focuses on subject-matter knowledge and deepens teachers’ content skills, (5) is grounded in standards that relates teacher work and student performance, and (6) connects with other aspects of school change (Supovitz & Turner, 2000).

Theoretically, high quality professional development that models these components should lead to inquiry based teaching practices, and ultimately improved student achievement. Research by Supovitz and Turner (2000) supports the claim that increasing amounts of professional development, supported by these six components, is statistically associated with both “greater teacher use of inquiry-based teaching practices and higher levels of investigative classroom culture.” Supovitz and Turner (2000) investigated the Local Systemic Change (LSC) initiative, a National Science Foundation funded program for primary and secondary science or math teachers. All of the 72 projects in this initiative shared a vision of science education reform, incorporating national content, teaching, professional development, and assessment standards. The projects should reach at least 80% of the teachers within the locality where they are run, and provide a minimum of 100 hours of professional development over the life of the project.

Participation in the project required participation in a core evaluation, which was analyzed by the researchers. They looked at surveys from 3,464 science teachers and 666 principals in 24 localities. Surveys asked teachers in detail about their attitudes about teaching, their classroom practices, their use of reform-based teaching, including hands-on work, and student driven investigation, and other classroom strategies, like classroom arrangement and cooperative discussion. They found that the increased professional development was statistically associated with both greater teacher use of inquiry-based teaching practices and higher levels of investigative classroom culture.

The NSES specifically state, “that inquiry instruction with students should include identifying researchable questions, designing and conducting experiments, developing explanations, thinking critically about the relationship between evidence and explanations, and communicating scientific procedures and explanations” (NRC, 1996; Luft, 2001). The complexity involved in learning to implement inquiry and doing it effectively throughout several units requires professional development. This professional development must first assess the practices and beliefs of science teachers (Luft, 2001). Loucks-Horsley and Stiles (2001) argue that inquiry experiences should unify both content and process. They suggest a common vision for science teacher professional development that includes (1) a commitment to the concept that all children can and should learn inquiry-based science; (2) the implementation and modeling of instructional methods to promote adult learning of science that mirror methods to be used with students; (3) building community and cultures of learning and enhancing the capacity of teachers to become science education leaders; (4) consciously designed structures that link professional development in science to other parts of the educational system; and (5)

programs that constantly review and assess their effectiveness. Science teachers need to not only learn to implement inquiry, but also expect feedback from peers or coordinators of the professional development activities designed around inquiry. According to Luft (2001), embedded in that feedback should be recognition that a teacher's belief structures are closely linked with their practice. This requires science teachers to explore and examine their underlying beliefs about teaching and learning inquiry in order to reform their conceptual framework (Luft, 2001).

It is accepted that teachers must have a deep-rooted understanding of content to teach inquiry. There are reform-based teacher preparation programs in place that center on inquiry-based, interdisciplinary models of teaching science, that focus on content and pedagogy as being inextricably linked (McGinnis, Parker, & Graeber, 2004). Pre-service teaching students work with faculty that model best practices, and are placed with teachers who are trained in reform models and serve as mentors. McGinnis, Parker and Graeber (2004) suggest that if teachers who are prepared to enact reform methods are evaluated through traditional methods, they are subject to criticism in their school districts. If, instead, they were evaluated by content supervisors using a reform-based assessment instrument, the situation would improve. Additionally, beginning science teachers would benefit from "induction networks" that extend beyond the school cultural boundaries, and into the community (McGinnis, Parker & Graeber, 2004).

Research into content-based professional development is growing. Jeanpierre, Oberhauser, and Freeman (2005) noted in their study that, "deep science content and development of science process skills with numerous opportunities for teachers to practice using integrated science processes and research skills" is a characteristic of

effective science professional development. They examined a 3-year project funded by the National Science Foundation at the Science Museum of Minnesota. Teachers and students participated in week-long summer institutes, and the groups were then visited twice during the academic year. Districts funded the participation of teachers and students, and teachers and students received stipends upon completion of the project. The groups worked for approximately 10 hours each day on an ecological activity involving a science inquiry topic – specifically the Monarch Larva Monitoring Project. Teams monitored their butterfly sites over extended periods of time, and ultimately presented the results of their research to project staff. The teachers showed a marked increase in incorporation of inquiry into their classroom practice, and an improvement in their own content understanding.

Birman et al. (2000) define a focus on content as “targeting a staff development activity on a specific subject area or on a subject-specific teaching method, such as increasing teachers’ understanding of motion in physics.” Lord (1991 as quoted in Little, 1993, p. 134) discusses subject-area collaborative professional development as an “alternative paradigm” in professional development. He states that such initiatives should encompass teachers’ knowledge of content, instruction, and students’ learning; their access to professional networks; and their leadership in system-wide structures.

Additionally, enhancement of teacher professional practices is crucial to science curriculum innovation. In following one teacher through a comprehensive professional development program, Peers, Diezmann, and Watters (2003) found that with appropriate professional support, a teacher’s professional practices in the classroom can be modified in a relatively short time frame, and that change is sustainable. They found the following

to be vital aspects of effective professional development: support from a mentor or researcher, discussion with professional colleagues, research and practice readings, and attendance at workshops that provide alternative teaching strategies.

Peers et al. (2003) used an interpretive approach to understand teaching actions. Specifically, one researcher (CEP) was a participant observer inside what they call the “scene of action” over three and a half months. The researchers collected contextual data regarding one teacher. A professional development plan was designed by the CEP for this teacher, which consisted of two-hour professional development workshops, conducted one week apart. These workshops focused on theoretical and practical approaches to constructivism in the science classroom. The other component of the professional development was ongoing support by the CEP as the teacher implemented a unit of work based on constructivist approaches into her own syllabus. After several months of weekly observations and visits, the teacher reflected with the CEP in a follow-up interview. In addition to the findings discussed above, Peers et al., found that the changes made by the teacher were maintained for at least two years.

One method for enhancing professional practice is through a mentoring relationship with college or university faculty. Often, teachers have a set of beliefs that they are unable to articulate in conjunction with current educational research. According to Sweeney (2003), “Teachers’ theories of their own professional practice consist of sets of beliefs, images, and constructs about such matters as what constitutes an educated person, the nature of knowledge, the society and psychology of student learning, [and] motivation and discipline.” The beliefs, called personal practice theories, guide teaching by linking personal experiences with those of practice. A program of mentoring

facilitated at the higher-education level allows teachers to take their personal beliefs and become a teacher-researcher – an active producer of theory and research rather than a consumer. A mentoring program consisting of classroom visits by the university professional, journal reflections by the teacher, and careful analysis of the teacher’s epistemological, social and personal beliefs can ultimately lead to a greater level of practitioner professionalism (Sweeney, 2003).

Lord (1994) advocated two approaches that provide hope in reinvigorating professional development experiences for teachers. The first of these is “critical collegueship.” This notion prompts teachers to engage in self-reflection, seek out best practice, increase empathy, hone communication skills, and be more open to uncertainty. Critical collegueship requires that teachers work with each other to evaluate and critique practice and planning, and creates an environment of disequilibrium surrounding practice. A critical colleague would allow for self-reflection and collegial dialogue, be open to new ideas and willing to reject weak practices, increase the capacity for empathetic understanding, sharpen skills and attributes associated with negotiation and resolution, and increase comfort levels regarding uncertainty. Lord’s second suggestion is to expand professional communities. Critical collegueship is practiced within a school building. Professional communities allow discourse between schools or districts, or across states. In this regard, teachers can seek out how others might be meeting the standards or implementing inquiry. They can also take on roles of leadership in these networks that differ from the roles they often take on in their schools.

While critical collegueship and professional communities do a great deal to enhance the teacher in critically reflecting on practice, they do not answer the question of

what are the key concepts that should be addressed in professional development, or the format and focus of professional development. Garet, et al. (2001), studied the effects of different characteristics of professional development on teachers' learning. Three core activities were suggested: (1) a focus on content knowledge, (2) opportunities for active learning, and (3) coherence with other activities. Content of professional development varies along four dimensions: the emphasis on subject matter and teaching methods, the specificity of the changes to teaching practice that are encouraged, the goals for student learning that are emphasized, and the emphasis they give to the ways students learn a particular subject matter. Garet et al. (2001) suggest that professional development requires a dual focus on both knowledge of subject matter content and an understanding of how children learn specific content. The second core feature, the opportunity to participate in active, meaningful learning, can take shape by observing or being observed by a peer, working during professional development to implement new ideas in individual teaching contexts, examining and reviewing student work, and offering teachers the opportunity to give presentations, lead discussions, and produce written work. Finally, for professional development to have a meaningful impact on teacher learning, it must be perceived by teachers to be part of a coherent program of learning. Coherence can be assessed three ways: (1) through connections with the teacher's goals, (2) alignment of content and pedagogy with activities emphasized by national, state, and local frameworks, and (3) communication with others who are engaged in reform efforts.

Garet et al. (2001) also examined the structural features of the activity, such as the form (i.e., study group or network), durations (i.e., the total number of contact hours spent on the activity by participants), and the degree of collective participation (i.e., are

groups from the same school or district?). From this research, it was determined that institutes, conferences, and courses, in general, are ineffective when compared to mentoring, coaching, or study groups as a means of transmitting professional development. The former refers to traditional forms of professional development that tend to take place outside of the teacher's school or classroom and involve a leader with specific expertise. The latter involves reform models of professional development that take place during the school day, even as part of classroom instruction. Additionally, Garet et al. (2001) suggest that professional development has to be sustained over time, thus allowing teachers the opportunity to implement new strategies, and reflect on them. The amount of time can be viewed in two ways – the contact hours between participants, and/or the duration of the professional development initiative. Collaboration also played a key role in facilitating discussion, especially among teachers in the same school, or same curriculum. Research suggests that focusing professional development on subject matter is especially powerful in changing teacher practice, as are promoting an active learning environment where teachers can engage meaningfully in planning and practice; the coherence of the professional development program; and how it aligns with standards and assessments, and supports communication (Garet et al., 2001).

According to Kwakman (2003), teachers' learning is embedded in everyday activities, and professional development does not necessarily have to take on the form of group meetings and in-service activities. Everyday school participation and striving towards personal goals can also be used as a means for professional development. Kwakman collected data on teachers' participation in what they deemed as professional learning activities. She did this through survey data and interviews. She then analyzed

those experiences for the underlying reasons behind the participation: personal factors (meaningfulness, accomplishment), task factors (pressure from work), and environment factors (collegial support). She received multiple examples of professional learning activities, including reading professional journals, coaching colleagues, working with student teachers, collaborating, and counseling. The varied forms of professional development suggested three learning principles.

The first learning principle focuses on school improvement and organizational development. This stresses the integration of work and professional development through organizational means (Kwakman, 2003). A second principle stems from the recognition that learning is not only individual, but social in nature; teachers may develop through self-directed learning projects out of their own initiatives (Kwakman, 2003). Dialogue and interactions with others, and the collaboration used to build a learning culture are all ways to stimulate professional growth. A third learning principle states that learning is a necessary component of professional development (Kwakman, 2003). Teachers must constantly strive for improvement in practice, in spite of or in conjunction with, other professional development opportunities.

Designing professional development that works requires an intense shift in our current design, as suggested previously. Professional development generally focuses on teacher deficit – it is designed to fill the gap. Smylie and Conyers (1991) recommend a program based on competency and self-reliance. Under this model, teachers' knowledge, skills, and experiences would be considered assets. Professional development would shift from dependency on external sources to self-reliant decision making. They also suggest a shift from professional development that focuses on transfer strategies to one

that promotes analysis and reflection. Analytical and reflective professional development requires autonomy on the part of the teacher. It will foster inquiry-based learning activities and emphasize problem solving. They call for collaboration, within the district and within the school. Teachers' collective wisdom would be tapped for solving problems related to the craft. Ideally, teachers' work-day schedules would be designed to allow for mentoring and coaching, hence changing the culture of the school. Finally, they recommend that professional development be decentralized. Teachers, administrators, and staff developers would work collectively to facilitate professional development activities. How is it accomplished? There is no blueprint for the how-to part of designing professional development. Each district has unique needs, and for this reason a defined "how-to" manual could not be fully conceptualized. It is, however, important to give staff developers and teachers an idea of where to begin.

A review of the body of literature in professional development for science teachers demonstrates a variety of outlooks and recommendations. In my review of the professional development literature, I am drawn to the thinking of Fishman, Marx, Best, and Tal (2002) because they present a framework for teacher learning that could be seen as a starting point for designing a professional development program. They argue that if content, strategies, location, and media, defined below, are controlled, noticeable changes in teacher and student learning may result that can be detected via statistical means. Content refers to what teachers should learn: should what teachers are learning through professional development be knowledge based and related to the pedagogy, or subject matter based? Strategies are "the pedagogical approaches employed to teach teacher professional development activities" (Fishman et al., 2002). Sites or locations can refer to

location of professional development or when it is held. It could imply an in-service, a summer workshop, or even an on-line activity. This leads to the question of media – should the activity be held in a face-to-face interaction, on video, or using the computer? Offering multiple sources of professional development allows teachers to engage in a way that is comfortable for them.

Fishman et al. (2002), also suggest an iterative model for evaluating professional development. They began with science education standards, and sought evidence of current student performance from artifacts, classroom behaviors, and other assessments related to curricular units. Next, they designed professional development intended to help teachers acquire the knowledge necessary to successfully enact the curricular unit(s). Teachers engaged in the professional development, and it was then evaluated through interviewing the teachers. Next, they observed classroom teaching, looking for evidence of teaching behaviors that matched what was taught during the professional development. Finally, the researchers re-assessed student performance, seeking to attribute changes in student learning to some aspect of the professional development activity. Results of this analysis require many iterations of refining the professional development model. The model, illustrated below in Figure 1, suggests a systemic approach, and a great deal of reflection on the part of the participants. This model is that is very closely linked with design and reflection.

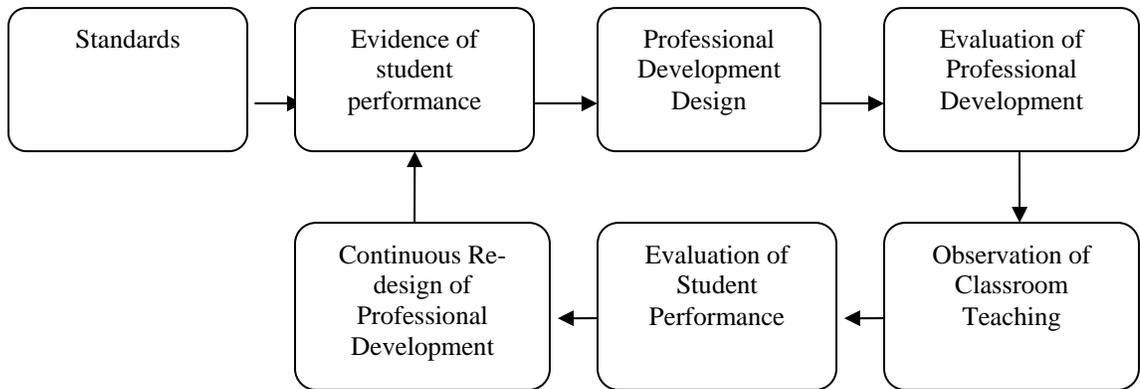


Figure 1: Systemic Approach to Professional Development (Fishman et al., 2002)

Changes in Practice

Much effort was spent in previous sections to discuss both teacher change and teacher learning. These two genres of thought, while considered separate entities to some, work in tandem when influencing changes in teacher practice (Richardson, 1990). In her review of what is necessary for worthwhile and significant change in teacher practice, Richardson (1990) cited two issues, organization and beliefs, as key to teachers' engagement, commitment, and willingness to change. Organizational issues include school conditions and teaching environment. Beliefs refer to the knowledge, attitudes, and perceptions of teachers, which may inhibit or promote change. For teachers to change their classroom practice, they first weigh the practicality of the change, whether it fits their situation, and cost. Teachers' beliefs about how students learn and what they ought to learn have greatest impact on whether or not they implement change. This is in stark contrast to early literature that once painted teachers as recalcitrant, resisting change because of their unscientific and stubborn nature. Richardson (1990) found that teachers exercise considerable control over change, largely because the focus has shifted from changing teachers' behaviors to changing their practical knowledge and cognitions.

Practical knowledge is gained from classroom experiences whereas empirical knowledge is shared by researchers. Additionally, teachers are more receptive if involved in the decision making and judgments surrounding the change - materials, thoughts, theories, or practices - and how should they be introduced. Finally, the context of change is significant - changes should be viewed within the cultural norms of their school, administration, students, peers, etc.

A more recent study of changing practice in the context of professional development provides significant insight into what kind of professional development activities foster greater classroom change. Porter et al. (2000) found that

Professional development focused on specific, higher order teaching strategies increases teachers' use of those strategies in the classroom. This effect is even stronger when the professional development activity is a reform type (i.e. teacher network or study group) rather than traditional workshop or conference; provides opportunities for active learning; is coherent or consistent with teachers' goals and other activities; and involves the participation of teachers from the same subject, grade, or school (p. 5).

They noted, however, if teachers are receiving professional development that varies in quality from year to year, little change in practice takes place. Professional development is effective when it focuses on the use of technology, instructional methods, and assessments that stress higher order thinking. Teachers whose professional development focused on using problems with no obvious solution reported increasing their use of this strategy, and if that professional development is structured in a reform-type way, the relationship was further strengthened. Professional development is most effective when

these features of quality are present: organization (whether it is reform type meaning study group or teacher network, or something more traditional), duration (referring to contact hours), collective participation (whether it engages teachers in the same school, district, etc.), active learning, coherence and content focus (Porter et al., 2000).

Summary

In this chapter, I reviewed the body of literature related to my central research question and the sub-questions. I included a historical overview of science education in the twentieth century. I then provided a summary of the relevant research on teacher learning and pedagogical content knowledge, professional development in science, and changing teachers' lines of inquiry and their classroom practice.

Understanding how teachers learn is productive and necessary in many endeavors – teacher education, professional development, and career-long training and recertification opportunities. Hopefully, understanding teacher learning will allow researchers to think about teaching more productively (Putnam & Borko, 2000). Teacher learning is both a social and situated experience. All knowledge is situated, but for teachers it is most meaningfully situated in their classrooms; in discussions with other teachers, university professors, and professional scientists; and in environments where they learn subject matter. Being situated does not imply that teachers cannot take their new learning and apply it in other settings. For this, expert teachers rely on their pedagogical content knowledge, on knowing how to successfully introduce concepts in a variety of settings because they know the learner.

Professional development is a necessary catalyst for meeting national science education standards. It can and should include an emphasis on content, including how

inquiry can be used to meet the NSES reform demands (Loucks-Horsley & Matsumoto, 1999; Garet et al., 2001; Ball & Cohen, 1999; Little, 1993). Professional development should be aligned not only with content standards, but also with teacher learning theory (Ball & Cohen, 1999). It should emphasize how teachers cultivate knowledge, analyze and critique their own professional work, and participate in communities of discourse on practice (Ball & Cohen, 1999; Jeanpierre, Oberhauser, & Freeman, 2005; Butler et al., 2004). Specifically, it should offer a wide array of experiences that allow teachers to build on prior knowledge, reflect on their own behaviors, evaluate what motivates them to learn, become aware of the processes of professional practices, and experience learning as a socially shared undertaking (Hawley & Valli, 1999). Good professional development has been defined as that which emphasizes student learning needs as well as the individual needs of the teacher, is intensive and sustained, focuses on concrete tasks, but orients them in theoretical understandings, integrates subject matter and standards, and connects to the school environment (Hawley & Valli, 1999; Supovitz & Turner, 2000).

Asking teachers to change can be difficult, both because change, in and of itself, is challenging, and because it takes time to implement, and even more time to see results. Professional development is one method for encouraging and supporting change. Change is most effective when it is supported by the teacher's school environment, is congruent with the teacher's beliefs, and benefits student learning.

In this study, I addressed the central question of how an intensive science professional development program affects science teachers' learning, and how this in turn affects their classroom practice. To answer this question, I used the research to develop

an understanding of what teacher learning is and how to situate it in the context of professional development, to determine the salient characteristics that constitute good professional development, and to understand teacher change in practice. The information garnered in this review of literature will be reflected later in Chapter 5.

In Chapter Three, I present the research design and methodology for this study. This will include the research design, conceptual framework, sampling procedures, description of the site, data gathering and analysis procedures including role negotiation, and assumptions related to trustworthiness, reliability, and bias.

Chapter 3: Methodology

“A case study is expected to catch the complexity of a single case. A single leaf, or even a single toothpick, has unique complexities – but rarely will we care enough to submit it to case study. We study a case when it itself is of very special interest. We look for the detail of interaction with its contexts. Case study is the study of the particularity and complexity of a single case, coming to understand its activity within important circumstances” (Stake, 1995, p. xi).

Overview

This chapter discusses the methods of inquiry, data collection, and analysis for this study, which is primarily qualitative in nature, but blends some quantitative data. Case study design was adopted to reveal how an intensive, content research-based professional development program affects science teachers’ learning and practice. A learning theory, constructivism, was used as the analytical framework. Purposeful sampling was used to select participants and the criteria and process for selecting the five participants, of which I am one, will be discussed. The data collection process and primary data sources, including interviews, observations, and surveys are discussed in detail. Data analysis is described, including the thematic coding mechanism chosen for the interview data and the simple statistical models used in evaluating the qualitative data. Finally, the design of the research is compared to established criteria relating to validity.

Research Design: Case Study

In broader, more generalized terms, this study followed qualitative design and methods. Qualitative work assumes a unique and complex nature for each social setting, which further requires large systems to be broken into more isolated variables (Erickson, 1986, as cited in Hatch, 2002, p. 9). Qualitative work builds a “case for the researcher’s interpretations by including enough detail and actual data to take the reader inside the social situation under examination” (Erickson, 1996, as cited by Hatch, 2002, p. 9). One of the most prevalent designs in qualitative research is the case study; this method was used to investigate how an intensive, content research-based professional development program affects science teachers’ learning. The context for this particular study was the Laboratory Science Teacher Professional Development Program (LSTPD) program in Berkeley. Each individual participant, myself included, represents one case.

Merriam (1998, p. 19) notes that case study research is effective in providing “intensive descriptions and analyses of a single unit or bounded system such as an individual, program or group.” A case study focuses on developing an in-depth analysis of a single case, and requires the researcher to set boundaries and prove that they have engaged in a purposeful sampling strategy in meeting those boundaries (Creswell, 1998, p. 64-65). Production of knowledge in a case study does not lead to generalizable conclusions; however, in examining the particular, some concrete universals are discovered that may be transferable to other contexts (Erickson, 1986, as cited in Merriam, 1998, p. 210). “The search is not for abstract universals arrived at by statistical generalizations from a sample to a population, but for concrete universals arrived at by

studying a specific case in great detail and then comparing it with other cases studied in equally great detail” (Erickson, 1986, p. 130 as quoted in Merriam, 1998).

Case study research is based on the participatory relationship between the researcher and the participant (Shank, 2002, p. 53). The case being studied generally refers to a program, event or activity involving individuals in a bounded system – one bounded by time and place. Cases are generally chosen because they represent an instance of the issue or hypothesis being studied; in this cases are bounded by their sameness (Merriam, 1998, p. 28). In the study presented here, the participants (cases) share a common theme of participation in the LSTPD program. To understand the participants’ perspectives, case studies are examined in their natural contexts. The researcher must spend sufficient time with participants to feel they are capturing the full picture (Erickson, 1986, as cited in Hatch, 2002, p. 8). Data are collected using observations, interviews, or other mechanisms. The important feature of a case study is that it is situated in context, whether that is a physical setting, or something socially or historically determined (Creswell, 1998, p. 61). Merriam (1998) describes case study research as particularistic, descriptive, and heuristic, meaning it focuses on a particular situation or phenomena, is thick with description, and illuminates the reader’s understanding of the phenomena under study.

Yin (2003) describes five components of the research design that are especially important in completing a case study. These are the study’s questions, propositions, unit of analysis, linking the data to the proposition, and determining the criteria for the study’s findings. Because I looked at the relationship between the program and the participants the case study methodology was most appropriate for the research questions in this study.

It was proposed here that teachers who participate in the LSTPD program think differently about their roles as teachers and that professional development enhances the view of learning and what they can do in their classrooms. While my research arena is the LSTPD , my unit of analysis was the individual participant – namely, the five individuals who participated in the study. Linking of the data to the propositions was accomplished through careful examination and coding of interview data, and then matching patterns in the data to the research questions and propositions. This was also critical in interpreting the findings- using established patterns allows for the data to be matched more clearly to the research questions. As patterns were recognized, categories were formed, and “the data are then read deductively” to determine if the categories support the overall set (Erickson, 1986, as cited in Hatch, 2002, p. 10).

In case studies, data are generally analyzed through descriptive narratives, intended to provide concrete details mixed with analysis and interpretation, all the while remaining interesting and informative (Merriam, 1998, p. 234). Erickson (1986) suggested three components as units in data analysis that are helpful in determining the balance between description and interpretation: particular description, general description, and interpretive commentary (as cited in Merriam, 1998, p. 235). Particular description refers to quotes from people interviewed, field notes, and vignettes of natural occurrence of the situation. General description provides the reader with a frame of reference as to whether the vignettes and quotes are typical of the data as a whole. Interpretive commentary “is necessary to guide the reader to see the analytic type of which the instance is a concrete token.... [and] thus points the reader to those details that

are salient for the author, and to the meaning-interpretations of the author” (Erickson, 1986, p. 152, as quoted in Merriam, 1998, p. 235).

Conceptual Framework

I organized my conceptual framework around constructivist (Bruner, 1996) and sociocultural (Vygotsky, 1986) learning theories (Figure 2). “Constructivism provides a basis for understanding how people incorporate new knowledge into existing knowledge and then make sense of that knowledge” (Ferguson, 2007). The sociocultural piece is directly related in that to construct knowledge, one must understand the social context in which it is being constructed (Bodner, 2007). I would argue that social constructivism as a theoretical framework is well suited for studies such as the present one, where the researcher intends to examine how the participants make sense of their professional development experience and the consequences of that experience for future classroom interactions (Ferguson, 2007). In Chapter 2, many instances of constructivism and sociocultural learning theory were presented in the context of studies on professional development. In relation to this research study, social constructivism is viewed as how teachers assimilate and accommodate new knowledge, beliefs, and experiences with their existing ideas, through social experiences and interactions.

For professional development to be successful, it should be designed around the learning needs of teachers. It should be situated in a context (Borko, 2004) that provides room for growth, discourse, and critique of current classroom practice and professional opportunities. It should emphasize inquiry about content and pedagogy, and provide points of reflection into their role as teachers of science.

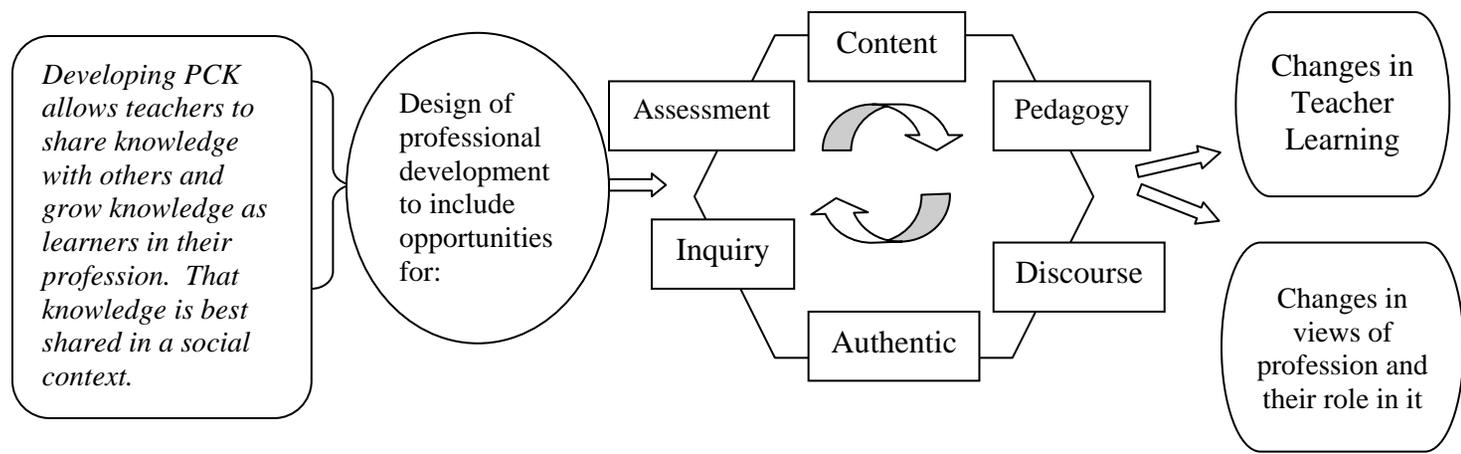


Figure 2: Framework of Professional Development

Professional development experiences for teachers should begin with the basic understanding of how teachers learn, and how knowledge is situated. I believe knowledge is socially constructed; in other words, teachers generate new understandings, and challenge prior conceptions when asked to participate in communities of discourse about practice. Communities can be made up of colleagues in the same building, district, or broader yet, field. Discourse should imply discussions about belief systems, reflection about practice, and opportunities for addressing challenges and success in the classroom. These communities could be conceived as professional development opportunities. Within these professional development opportunities are six fundamental units (assessment, content, pedagogy, discourse, authentic, and inquiry). They follow in no particular order, but are all necessary in tandem with each other. For learning to be situated, context is necessary (Ball & Cohen, 2003; Butler et al., 2004; Garet et al., 2001; Jeanpierre et al., 2004; Loucks-Horsley & Matsumoto, 1999; Loucks-Horsley et al., 2003; Putnam & Borko, 2000) in that:

1. The experience should engage teachers in the practice in inquiry. As discussed earlier, teachers are asked to engage in inquiry in their own teaching, and therefore should be trained in the same model they are asked to teach. Teachers should work with materials that they can later use in their classroom. Even if teachers work in a laboratory setting that is more sophisticated than their own classroom setting, they should be exposed to experiences that they could adapt to meet the needs of their students.
2. To develop as a science teacher, one must be exposed to science content. Part of teaching science means continuing your personal journey as a scientist. In

addition to content development is the fundamentally important area of pedagogy development. While understanding advances in science is essential to teaching science, without an understanding of pedagogy, there is no possibility of teaching it effectively.

3. Finally, a good professional development experience focused on teacher learning should allow for teacher discourse. This allows for reflection, collaboration, and critique of the field.

The ultimate measure of the program is its effects on teacher learning, and the teachers' views of the profession of science teaching. This can be best understood by in-depth interviews with teachers during and after their professional development and teaching experiences.

Sampling

The participants in this study were recruited from the Laboratory Science Teacher Professional Development (LSTPD) program housed at the Ernest O. Lawrence Berkeley Lab in Berkeley, California. The LSTPD is a three-year professional development model. The Teacher as Researcher program, one facet of LSTPD, matches science and mathematics teachers with Department of Energy funded researchers to act as mentors. The participants in this study were teachers in their second or third year of participation in the program. Through this research experience, teachers participated actively in an on-going research program with a laboratory scientist.

Participants in the LSTPD program applied online. The program is advertised at area conventions, such as the National Science Teachers Association Convention. Participants could apply to a number of laboratory settings, each with unique offerings.

The program in Berkeley is perhaps the most eclectic because there a number of different scientific disciplines housed there.

Because I am a participant in the LSTPD program and belong to the electronic listserv, I was able to contact all participants using electronic mail. Four secondary science teachers responded with interest. In recognition of the potential value of my own perspective as a teacher participant in the LSTPD, I was also a participant in the study, for a total of five participants (Table 1). The following is a brief description of each participant's background at the time of the study (pseudonyms used for all, except for the study's researcher:

1. Melissa, the researcher, has six years of teaching experience in high school. She has taught Chemistry, AP Environmental Science, and Introduction to Chemistry and Physics. She has a bachelor's degree in Chemistry and a master's in Teaching. She teaches in a suburban area in Maryland.
2. Angela has 10 years of teaching experience in high school. She has taught Introducing to Physics, Biology, and Physical Science. She teaches in an urban setting just outside of a major west-coast city. She has been in this assignment for 3 years. Angela is an outgoing individual, evidenced by the length and ease of her interview.
3. John has been teaching for 11 years in a suburban district on the west coast. He is the department head for science, and has spent his entire career at this school. He has taught AP chemistry, chemistry, biology, integrated science, and general science. He attended the University of California Berkeley, and

has worked at the lab since the beginning of his teaching career. John is a loquacious and reflective.

4. Adam is a third year teacher at a small high school in the northeastern United State. He transitioned from work as an engineer to teaching chemistry and physics. Adam has an undergraduate degree in engineering and earned his teaching credentials through a program in his hometown. Adam is very succinct in thoughts and actions, and attributes this to his engineering training.
5. Bridget is a fourth year teacher who is at her second school. She has experience teaching ninth grade science (physical), biology, and earth science. She teaches at a suburban high school on the west coast. She earned a degree in biology, but chose teaching after graduation. She earned her teaching credentials at a local college in her town. Bridget is often tentative in group settings as she processes information from more seasoned teachers.

<i>Participant</i>	<i>Years of teaching experience</i>	<i>Year in LSTPD program</i>	<i>Student Grade Level</i>	<i>Subjects Taught</i>
Melissa	6	2	10-12	Chemistry, AP Environmental Science, Introduction to Chemistry and Physics
Angela	10	3	9-12	Introducing to Physics, Biology, Physical Science
John	11	3	10-12	AP chemistry, Chemistry, Biology, Integrated Science, General Science
Adam	3	2	11-12	Chemistry and Physics
Bridget	4	2	9-10	Physical science, Biology, Earth Science

Table 2: Participants' Demographic Information

Research Site

The focus of this study was to examine one professional development program that seems to embody many of the characteristics of good professional development for science teachers. The LSTPD program places science teachers in a laboratory setting where they work as research assistants with Department of Energy scientists. The areas of expertise at the lab range to accommodate any participant: environmental science, physics, chemistry, astronomy and others. I participated in the first year of this program for a six week interval, and studied atmospheric particulate matter and the impact it had on visibility in the western United States. In my second summer, I was at the lab and researched for a period of eight weeks (this time in physical chemistry). The program is designed to facilitate inquiry. Teachers design questions and research them while

working closely with a mentor (researcher). It is intensive in that teachers are completely immersed in the program for a time period between two and eight weeks. It is sustained over a three-year period, consisting primarily of the summer fellowship. It engages teachers in concrete tasks around science and pedagogy in that teachers ultimately take their research agenda and transform it into a program they can use in their school. Teachers receive funding to purchase necessary materials to make sure that happens. It is grounded in standards (Appendix B) in that it focuses on teacher professional growth, inquiry, and appropriate assessment (Supovitz & Turner, 2000).

The Laboratory Science Teacher Professional Development Program (LSTPD) is run through the United States Department of Energy (DOE). While the DOE has worked extensively over the past several years to involve teachers in professional development activities, none have been as intense and continuous as the LSTPD initiative. The program was designed specifically for teachers of science and math to increase content knowledge through scientific research experiences. Teachers must apply and be accepted to participate. It requires a three-year commitment on the part of the teacher, and he or she is placed at DOE National Laboratories across the country: Argonne National Laboratory in Argonne, IL; Brookhaven National Laboratory in Long Island, NY; Lawrence Berkeley National Laboratory in Berkeley, CA; National Renewable Energy Laboratory in Golden, CO; Oak Ridge National Laboratory in Oak Ridge, TN; Pacific Northwest National Laboratory in Richland, WA; and the Thomas Jefferson National Accelerator Laboratory in Newport News, VA. Researchers serve as mentors to teachers and guide them through current advancements in their field.

Teachers are obligated, during their first summer, to spend between four and eight weeks in the program. Those who live nearby commute to the lab. Those who are traveling cross-country are given a housing allowance and assisted in finding a temporary housing placement. Teachers are assisted with their traveling expenses and are paid a stipend during their time at the lab. Teachers apply for specific programs at the lab (like Teacher as Researcher), so in some instances teachers participating are in different programs. All teachers in this study were part of the Teacher as Researcher program. Regardless, the science teachers meet as a group at least once per week to discuss issues related to professional development and classroom practice. They must also submit work samples (Appendix D) that exemplify where they were in their teaching prior to attending the LSTPD program, and how they might use the program to influence their teaching and student achievement. During the school year, the science teachers are asked to re-submit a second work sample and show how they used the knowledge gained from LSTPD in their teaching.

The science teachers in their second and third years in the program may commit to as little as four weeks of time (in other labs, it can be as little as two). Each lab runs its own individual programs that range in length. Teachers may switch from one lab to another each summer, yet all are encouraged to stay at the lab where they did their first year's work. Upon completion of each summer, teachers are given a stipend that is designated for purchasing classroom supplies and attending professional conferences. A certain portion of the stipend is designated for each activity. Teachers are encouraged to attend conferences sponsored by professional organizations such as the National Science Teachers Association, the American Association for the Advancement of Science, or the

content specific associations. Teachers are also encouraged to present on behalf of the LSTPD program to recruit applicants from a larger pool of teachers. During the school year, directors from the lab visit teachers at their home schools and discuss their work with LSTPD. Additionally, teachers are encouraged to remain in contact with each other through the use of online forums.

Data Collection

Prior to arriving at the lab in the summer of 2006, I contacted each participant once via telephone to request participation, after which time I sent one electronic communication that outlined the goals of my study. My data collection was facilitated through the Department of Energy which permitted me to access the database of science teachers who are new to the program or returning. I began the data collection and initial analysis immediately in the summer and continued my work with the participants until they completed their time at the lab. This end time varied for each participant, ranging from mid-July to early-August. I corresponded with them through email journaling and interviewing on a weekly basis. I followed up with participants using electronic mail after they left the lab.

The invited participants received a study description that included the purpose of the study and an explanation of the possible risks and benefits. The five teachers who participated were given consent forms. Interview schedules were then developed for each participant for both of the two individual interviews, and the larger focus group interview. Data were generated in the following ways: two in-depth individual interviews (Appendix E), one focus group interview with all participants, an observation of the teacher in their lab area, a content self-assessment survey completed at the lab

(Appendix A; Appendix B) and generated by the head of the professional development program, and a follow-up reflective questionnaire, submitted electronically at the end of the following school year (Appendix F). A brief timeline is shown in Figure 3.

In a case study, traditionally, a bounded system is investigated (Erickson, 1986; Merriam, 1998; Yin, 2003). In this case, that system is the LSTPD program. I was able to gain access to this system by virtue of being a participant in the program.

Additionally, however, I needed to gain permission to study other participants. This was done through the Department of Energy. There are few participants at each location of the program. For example, in 2004, the Berkeley Lab had 14 participants. This number changes as the program changes and ages. Participants agree to three summers of participation, meaning that there will be three stages of participation. In the summer of 2006 when I conducted this research, there were teachers completing their third year and those in their second; new participants were not brought into the program that year, and would not be until the summer of 2007. I studied three participants in their second year of the program, and two in their third year.

As earlier reported, quantitative data were collected using a survey generated by the Department of Energy called a Content Self-Assessment Survey (Appendix A). All participants in the LSTPD program completed the survey. I was given permission to view the results of 14 of these surveys, 5 of which were the participants in this study. All were used to gain a baseline understanding of the teaching in which the LSTPD participants engage, how often they participate in professional development, what types of assessment they currently use in their classroom, and what they hope to gain from the

program. I used this data to cross-reference points made on these same topics during our interviews. It served as a data source, but also a way to triangulate my data.

Qualitative data collection relied primarily on interviews. Interviews are the most coming form of data collection in qualitative research (Merriam, 1998, p. 71).

We interview people to find out from them those things we cannot directly observe.... We cannot observe feelings, thoughts, and intentions.... We cannot observe how people have organized the world and the meaning they attach to what goes on in the world. We have to ask people questions about these things. The purpose of interviewing, then, is to allow us to enter into the other person's perspective (Patton, 1990, p. 196, as quoted in Merriam, 1998, p. 72).

I met with participants on three occasions – once, individually in the first two weeks at the lab, once as a focus group at the end of the second week, and finally, individually at the end of the professional development experience. This was necessitated by the fact that participants may choose to work at the lab for as little as four weeks or as many as eight weeks; only one of the five participants was at the lab for four weeks. These interviews were audio-recorded, and transcribed. Additionally, I took notes during the interviews and used those notes to aide in transcription. This information was stored in locked storage bins in my place of residence.

A series of interview questions were generated based on the research questions (Appendix D). There were certain areas of inquiry that I saw as important when developing the questions:

- Do teachers view themselves as professionals? How does the teacher define professionalism? What are examples of occupations that employ professionals?

- If they have participated in outside professional development opportunities, did they receive funding from their district?
- Do they feel that we have a community of science teachers? Do they feel that the district officials support their needs and endeavors?
- Do teachers receive quality professional development? What do teachers feel in quality professional development? What do districts feel in quality professional development? Are all teachers in need of the same professional development?
- What form of professional development would most benefit teachers? What could enhance the professional experiences of teachers in terms of pedagogy and content?

The interview protocol followed suggestions provided in Shank (2002, pp. 44-45).

There was a short list of questions for each session and then time for conversation.

Participants received anonymity through a coding system, and I made note of who was speaking using these codes. It was important that each participant answer each question during the focus group interview; I directed questions to different participants to begin each conversation in order to facilitate this.

To manage the data, I began transcribing immediately after the interviews, making notes of emergent patterns, and beginning the process of coding the interviews. I used this information to find gaps in my interview questions and my understanding of the individual context in which each of the participants teach. I used subsequent interviews to fill in these gaps. I also used electronic correspondence to follow up with participants when necessary.

Mid-way through the professional development experience, I visited participants in their lab area and made observations. Observations are often used in qualitative research to provide the researcher with a firsthand encounter with the phenomenon of interest and to triangulate findings when used in conjunction with interview data and field notes (Merriam, 1998, pp. 95-96). Merriam (1998, pp. 97-98) suggested elements to note when observing (all of which were employed for this study): the physical setting, the participant, activities and interactions, conversations, subtle factors, and the researcher's own behavior. I looked at the kind of work they were doing, the instrumentation they utilized, and conversed with them about prior experience they may have had in this environment. Additionally, the participants and I discussed the differences between this work-space and that of their classrooms. For me, the observation was used to help in my understanding of the kind of experience each participant had at the lab, fostering richer interview conversation.

I contacted participants during the last months of the school year (ending in May) using electronic mail. The use of electronic mail was chosen based on what was indicated as most convenient for all of the participants. Being teachers, none of the participants is reachable by telephone during the workday, and all, myself included, are disinclined to continue our professional lives during personal time. Electronic mail allowed the participants to respond to questions during "off" times of their workday, like before and after school, or during planning periods. The goal of the questions sent at that time was to assess whether the teachers had changed their practice, or their views on professionalism and professional development, as a result of their participation in the program. Each

individual was provided with a copy of their case study for review to check for accuracy of the facts, and plausibility of the conclusions (Merriam, 1998).

Role Negotiation

I was in a unique position in conducting this study. Having previously participated in the LSTPD program, I was acquainted well with three of the individuals who volunteered to participate in my study. I too am a participant in my study and in the LSTPD program. Because of this, I had to navigate between the roles of researcher during my individual interviews and observations, and participant during the focus group interview. I attempted to neutralize any impact that my friendship with the participants had on data collection, as will be discussed later in this chapter. Given my unique situation, it was not difficult to gain insight into the knowledge, beliefs, and practices of those who participated in my study.

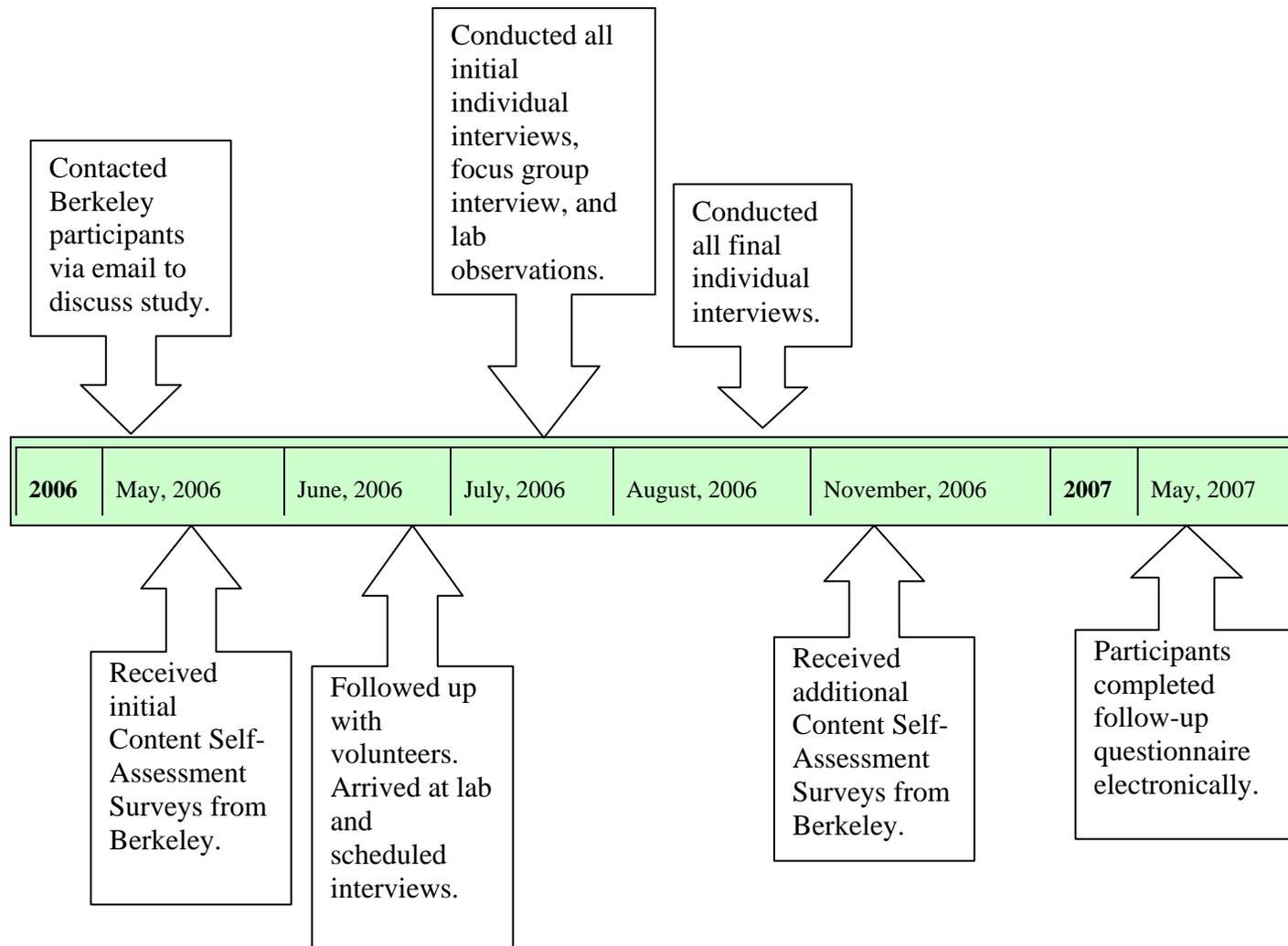


Figure 3: Timeline of Data Collection

Data Analysis

Several sources provide information on the impact that the LSTPD program had on teachers' learning. First, teachers completed a survey, designed by the program leaders in Berkeley, where they indicated how often they engage in varied types of professional development, how effective they are at integrating new skills into their teaching, how frequently they engage their students in a variety of inquiry lessons, how often they collaborate with other teachers on different activities, and finally the effectiveness of their assessment practices (Appendix A). These data were used to inform the qualitative design.

The pre-participation survey was evaluated using simple percentages to determine the frequency that teachers implemented the criteria described above. These data were then used to develop categories for participants, including: (1) those that often/seldom participate in professional development activities; (2) those that feel effective/ineffective in integrating reform methods; (3) those that frequently/infrequently engage students in inquiry modeling; (4) those that collaborate/do not collaborate with colleagues; and (5) those that employ/do not employ varied assessment techniques.

To clearly portray the multiple stories of the teachers, relevant data were extracted from field notes, the author's journal, and other sources mentioned earlier. The transcribed interviews were reviewed and coded into units of meaning. Recognition of patterns embedded in the qualitative data and the capturing of these patterns into meaningful arrangements allowed the author to develop emergent themes. These themes were: current work in the program, professional development background, beliefs about professional development and professionalism, and connections to practice.

The qualitative data consisted largely of taped interviews and field notes. Data were analyzed through an inductive approach (Merriam, 1998, p. 60-61). Analytic induction is a process of continual refinement of the research questions until discrepant events emerge. Ultimately the research hypothesis evolved so that it explained the phenomenon at hand (Merriam, 1998). According to Merriam (1998), there are five basic steps in inductive analysis: (1) begin with a tentative hypothesis of the phenomenon under study; (2) select an instance of the phenomenon to see if the hypothesis fits the case; (3) if it does not fit, reformulate the hypothesis, and if it does, select other cases to test; (4) look for cases that do not fit; (5) continue until no negative cases are found.

First, interviews were transcribed and line numbers assigned to transcripts. Pseudonyms were assigned to each participant to ensure confidentiality. The data were sorted based on its fit into topics reflecting my research questions, and the results of the pre-participation survey. A set of codes, or thematic analysis, was constructed that captures the meaning expressed by the data. Once the data were coded, tables were constructed to summarize the data and allow me to check for patterns. At that point, I evaluated the plausibility of the emerging patterns by searching for negative instances of patterns, and incorporating these into the larger construct (Marshall & Rossman, 1999; Shank, 2002). The final report presents data from the participants' perspectives, presenting their views as analyzed through the conceptual framework.

Trustworthiness, Reliability, and Bias

A case study requires extensive verification (Merriam, 1998; Yin, 2003). Two aspects of trustworthiness should be performed: triangulation and member checking

(Stake quoted in Creswell, 1998). Triangulation refers to searching for convergence of information. Any description in the study that could be contested should be triangulated. The researcher must confirm these statements through a protocol described by Denzin (quoted in Creswell, 1998): data sources, investigator, theory, and methodological. Member checking refers to asking participants to examine and comment on rough drafts in which their actions or words are featured. Stake also provides a “critique checklist” (Stake quoted in Creswell, 1998) for assessing a case study that includes access/site questions, observations, interviews, document research, journals, video materials, and ethical issues (Creswell, 1998, p.214). The researcher should ask herself the following: (1) is the report easy to read?; (2) does the report have a conceptual structure?; (3) is the case adequately defined?; (4) is the reader provided vicarious experiences?; (5) are headings, figures, artifacts, appendixes, and indexes used effectively?; (6) has the writer made sound assertions?; (7) were sufficient raw data presented?; (8) do observations and interpretations appear to have been triangulated?; (9) is the role and point of view of the researcher nicely apparent?; (10) is the nature of the intended audience apparent?; (11) is empathy shown for all sides?; (12) are personal intentions examined?

I believe the largest threat to trustworthiness that I faced in this research was researcher bias. As stated in Maxwell (1996, p. 90), the researcher runs the risk of fitting data to an existing theory or preconception, or selecting data that stands out to the researcher. Maxwell also addresses the impossibility of eliminating these threats entirely, called *reflexivity*. Reflexivity, Maxwell states, is why “it is clearly impossible to deal with [threats to trustworthiness] by eliminating the researcher’s theories, preconceptions, or values” (1996, p. 91). The power of qualitative research is that it is concerned with

eliminating variance between researchers in values and expectations that are brought to the study, and establishing understanding about how a researcher's values influence the conduct and conclusions of the study (Maxwell, 1996). Therefore, it is essential that all possible biases be explained in the proposal.

This research focused on the secondary science community. Its goal was to address the professional growth needs of secondary science teachers through improved professional development experiences. As I detailed earlier in chapter one, I am a member of this community, and have agonized throughout my career over the topic of professional development of science teachers. I share the frustrations of sitting through workshops that are seemingly inapplicable to my classroom setting, and engage in the same conversations with colleagues – “Remember several years ago they did that professional development we all liked. Couldn't they do that again?” Our frustration as a cadre of professionals eventually turns to cynicism and apathy. I have to remove myself, to a certain extent, from my role as a fellow teacher to assess the issue, for fear of researcher bias. While I believe that my title of “chemistry teacher” allowed me access to individuals and resources that a researcher might have more difficulty acquiring, it also opened me up to a new set of problems that I will address. Mainly, my concerns centered on:

- Getting people to respond to requests for information
- Determining whether one can understand a setting when one is close to it
- Assuming an observer role and how to change roles
- Saying “little” during interviews
- Using an appropriate level of questioning in interviews

- “Bracketing” personal bias

Methods of triangulation and member checking were employed to reduce methodological threats. During the interview, member checking consists of the researcher restating, summarizing, or paraphrasing the information received from a respondent to ensure that what was heard or written down is in fact correct. Following data collection, member checking consists of reporting back preliminary findings to respondents or participants, asking for critical commentary on the findings, and potentially incorporating these critiques into the findings (Lincoln & Guba, 1981 as quoted in Marshall & Rossman, 1999).

Additionally, this study met the standards of quality discussed by Lincoln and Guba (quoted in Marshall & Rossman, 1999). The first is *credibility*. My goal was to demonstrate that the inquiry was conducted in such a manner as to ensure that any participant was accurately described. The aim of this project was to explore a problem in the setting where it exists, and interview those directly impacted by its presence. The more detailed and rich descriptions of the setting and interviews were, the more valid the data were. It was also important to accurately state the parameters of the setting, population, and theoretical framework under which the research was conducted.

The study must exhibit, to a certain extent, *transferability*. I will argue here that I believe this study will be useful to others in similar situation with similar research questions or questions of practice. The application of findings to other settings can be an arduous task. It is important that the researcher employs a strong theoretical framework to show how data collection and analysis were guided by concepts and models. For example, linking research on teacher perceptions of professionalism with professional

development opportunities allowed this research to be used in a variety of settings and hence enhanced transferability. Triangulation also assisted here. “Triangulation is the act of bringing more than one source of data to bear on a single point” (Marshall & Rossman, 1999, p. 194). Data from different sources were used to corroborate and elaborate the research question. The use of multiple cases, multiple informants, and more than one data-gathering method strengthened the plausibility of this study being employed in other settings.

A qualitative study must also exhibit the construct of *dependability*. Here, I attempted to account for changing conditions in the study. Because the world is always changing and being constructed, the researcher must be extremely careful to refine understanding in a setting and achieve dependable data.

The final construct is *confirmability*. The researcher must ask whether the finding of this study could be confirmed in another. “By doing so, they remove evaluation from some inherent characteristic of the researcher (objectivity) and place it squarely on the data themselves” (Marshall & Rossman, 1999, p. 194).

Being in a setting does not in itself provide credibility in an account. However, the researcher’s presence is essential. The researcher’s presence can lead to heightened sensitivity to the subtle understanding of the population that would not be available to the detached observer. However, the researcher must be careful of reactivity – contaminating the research by influencing how participants behave or talk. Given that I was in direct contact with the population prior to the start of this research, I had to be careful of reactivity. At the same time, I believe my closeness to the research gave me a sense of credibility that an outsider might have to earn.

As an educational researcher, I actively engaged in interpretation and selection – noting some things as significant and ignoring what was not significant. Multiple descriptions of the same event are plausible and provide credibility. Qualitative research is summed up as a matter of selective experiences and one must acknowledge the necessity of reducing the complex social experiences that one observes. Selectivity must be purposeful, circumstantial, intuitive and empathetic.

As an educational researcher, you must assume a dual responsibility to engage with others while remaining faithful to the aim of conducting the research; Schram (2003) refers to this as *posturing*. Researchers must decide how to present themselves to the participants – when does one play the researcher, and when does one take on other multiple roles you may need to assume? In the case of this research, this may be as a science teacher, a leader of professional development, or a peer. There are varying degrees of presentation in qualitative research including rapport building, friendship developing, and boundary spanning that the researcher must address (Schram, 2003). All of these can lead to researcher bias, and call researchers to maintain as neutral a stance as is plausible for the research design.

I will attend to the concerns of trustworthiness and bias. The researcher must grapple with what knowledge to share with the participants in order to establish trust without jeopardizing the research study. The researcher must ask herself: (1) am I deceiving participants or putting them at risk?; (2) how much should I tell participants about my sense of the problem?; (3) should I let participants know that the focus of the study might shift as it proceeds? Qualitative research carries with it the unavoidable potential for deception. This requires researchers to engage in the ethical standards and

requirements of informed consent, where they make clear that it would be unethical to misrepresent their identity, misrepresent the purpose of the data, or break promises to people engaged in the data. The researcher must inform participants fully about the study's purpose, what their participation entails, that participation is voluntary and must be done willingly, and that they may withdraw from the study without persecution of any kind.

Bias was perhaps the largest concern in this study. Given the nature of the relationships that I had with the participants, I had to be particularly careful of how I gathered and interpreted data. All participants in the LSTPD program were asked if they would be interested in volunteering for my study. For the most part, those who volunteered happened to have the closest personal relationships with me, and I suspect this is why they volunteered. These were people with whom I had shared my first summer at the lab, and with whom I had spent time outside of the lab. Thankfully, LSTPD program coordinators carefully vet applicants, and all teachers who engaged in this study were, by the program's standards and my own, exceptional people with a keen interest in sharing their views on the program. All participants received the approved IRB consent form well in advance of the research. This detailed the study's purpose, what participation entailed, and that their voluntary cooperation could be withdrawn at any time. When conducting interviews, I shared interview questions with the participants before beginning, so as to limit putting my own opinion in the interview. When the teachers offered their opinion, I often replied with something anecdotal – a story of my own classroom experiences that mimicked their opinion. This allowed them to feel more comfortable in continuing to share their personal feelings. During the initial interviews, I

felt a sense of urgency to discuss pedagogical content knowledge with the whole group. I explained this when we met for the focus group interview, and described why my focus shifted. To address any concerns about misrepresenting data, transcribed interviews were shared with the participants as a way of “member-checking” the transcription. The final analysis of their work (this dissertation report) was also shared with them.

“The dialectic that informs much qualitative fieldwork – that is, unexpectedly acquired knowledge suggesting previously unforeseen questions leading to new directions for inquiry – heightens the risk of being misunderstood” (Schram, 2003, p. 105). The researcher must engage in the following: periodically remind participants why you are there; remain aware of the boundaries you establish to refine the purpose and focus of the study; set up opportunities to discuss the relative boundaries of power among participants; be clear about motivations and intentions when engaging participants in activities that are for research purposes; and help participants maintain some sense of the nature and scope of what you intend for rapport.

Summary

This study aimed to identify how an intensive, content research-based professional development program affects science teachers’ learning and how this, in turn, affects their classroom practice. This was examined by first addressing how these teachers learn through professional development and their understanding of PCK. In order to address these questions, the study followed a qualitative case study design where the unit of analysis was teacher change. Participants for this study were selected based on prior experience in the LSTPD program, and their willingness to participate. Data collection included two individualized interviews with standard questions, a focus-group

interview, one observation of the workspace, a Content Self-Assessment survey developed by the LSTPD program leaders, and an open-ended questionnaire, administered electronically at the end of the next school year. All data sources were analyzed for evidence of the influence of the LSTPD on learning, the beliefs, and the PCK of practicing teachers and its changes in practice. Conclusions were drawn through the processes of analytic induction and deductive analysis (Patton, 1990). Thematic strands were identified in field notes, interview responses, and artifacts. Cases were constructed through an iterative process of theme generation, triangulation, and within case analysis. Final cases were subjected to cross case analysis resulting in emergent themes that were examined against data in search for discrepancies. Chapter 4 presents the findings of this study.

Chapter 4: Findings and Insights

“Perhaps the major point about case studies to keep in mind is that they are richly descriptive in order to afford the reader the vicarious experience of having been there.... Detailed description of particulars is needed so that the reader can vicariously experience the setting of the study... [and] for the reader to assess the evidence upon which the researcher’s analysis is based” (Merriam, 1998, p. 238).

Overview

The purpose of this study was to investigate how an intensive, content -based professional development program affects science teachers’ learning, and how they transfer that into classroom practice. To fully understand the impact of the LSTPD program on the participants, I first explored how these teachers thought and felt about professional development. This included questioning about their professional development background, and their current needs, and finally, their views on the LSTPD program as a type of professional development. Second, teachers reflected on the connections between PCK, context and learning, and explored, as a group, how these were influenced by their training, current experience, and their experience in LSTPD. Finally, in later interviews, I questioned teachers about how their views of practice have changed as a result of program participation, and how those changes will manifest themselves in their classrooms. Also discussed was professional development as a way of learning new content and pedagogy.

The quantitative analysis is presented first. The data allowed me to see where the participants fell on a continuum at the start of their experience at the lab. I examined four areas: History and Nature of Science, Science as Inquiry, Science and Technology, and Science in Personal and Social Perspectives. After the quantitative analysis, questions that were previously generated for interviews were modified to reflect salient points from the quantitative data.

The participants' experiences in the study are displayed as case studies using their words to describe four main areas of interest: Current Work in the LSTPD Program, Professional Development Background, Beliefs about Professional Development and Professionalism, and their Personal and Professional Goals and Reflections

Findings of the Quantitative Data Analysis: Teachers' Self-Assessment

A survey (Appendix A) was designed by the Berkeley Lab to elicit teachers' self-assessment of their practice. The survey was administered prior to the first summer of work at the lab. The survey examined their content knowledge and the frequency that they taught or interacted with science as inquiry, science and technology, science in personal and social perspectives, and the history and nature of science. Because the content portion of the survey varied depending on what the teacher is certified to teach, I focused my analysis on the broader categories. I compiled the data of all teacher participants (14), including the five who agreed to participate in my study, as percentages. A discussion of the data follows with special attention given to those survey questions that connect with my study. A sampling of the data is included, with the full data being reported in Appendix B. This survey was not administered post-participation. It was given to program participants prior to their arrival at the lab in 2004, and copies

were given to me before returning to the lab in 2006. The data analysis provided certain insights, discussed in this section which aided in the development of the interview protocol. Examples are provided within the following discussion.

Data were analyzed using simple percentages to ascertain the frequency that teachers were involved in certain activities. At first glance, the survey seems to present ordinal data, as teachers are indicating an option along a scale of 1-5. In reality, the survey is categorical, meaning that teachers indicated to which category they belonged for each question. For example, on the Science as Inquiry portion of the survey, teachers are asked to indicate for “Design and conduct scientific investigations” whether they (5) teach that frequently, (4) teach it occasionally, (3) had a course or professional development experience on it, (2) had some knowledge about it, or (1) were vague or unfamiliar with it. The numbers do not necessarily indicate any level of skill along a continuum, but teachers were told they could only choose one answer for each question. Teachers merely associated themselves with particular categories of use or understanding on the variety of topics presented in the survey. The numbers were simply used for data entry purposes by the survey developers in Berkeley, when logging answers the teachers chose.

Scientific inquiry is the basis for the LSTPD program. Teachers are brought to the lab to engage in a real-time study of a scientific question. Lab researchers see a need for a study, and it unfolds. Teachers contributed in a variety of ways. Prior to their arrival at the lab, 71% of teachers reported that they frequently teach students how to identify questions and concepts, design and conduct experiments, and use technology, but only 29% carry it through to teach students how to formulate and revise their explanation,

recognize alternate explanations, and communicate and defend their results. Given these data, I asked the participants to discuss how they would take the experience of working at the lab and integrate it into their classroom.

Little scientific research is conducted without the use of technology. “In today’s world, technology is a complex social enterprise that includes not only research, design, and crafts, but also finance, manufacturing, management, labor, marketing, and maintenance” (AAAS, 1989). Most participants (57%) in the LSTPD program have some interaction with technology, and occasionally integrate it into their classroom teaching. For some (14%), their interaction is limited to professional development experiences. The majority (57-71%) had no interaction with the type of technology present at the lab, specifically synchotrons and supercomputers. Because of the importance of technology and the daily interaction with it at the lab, I asked study participants to discuss how they would integrate technology into the classroom, and their level of comfort with technology given this experience.

Data that I found quite useful in considering interview questions were found under “Science in Personal and Social Perspectives.” *Context* is a buzzword among science teachers – how can you provide context for the abstract concepts that you sometimes must teach? Concepts like health, natural resources, environmental quality, and hazards can be integrated into any science course, and are a good way to springboard a discussion on how applicable science is in the everyday lives of students. The data were split, however. Many teachers had experience with these perspectives through professional development, or personal knowledge, but few integrated them into their

classroom frequently (14%). I discussed context with teachers during the focus group interview, though the discussion of PCK.

Within the realm of educational research and standards, “Nature of Science” is a predominant theme (AAAS, 1993). “When people know how scientists go about their work and reach scientific conclusions, and what the limitations of such conclusions are, they are more likely to react thoughtfully to scientific claims and less likely to reject them out of hand or accept them uncritically” (AAAS, 1993). Because of its recent emphasis, many teachers were familiar with the concepts of science as a human endeavor, and the nature of scientific knowledge. Most are teaching ideas related to these concepts (i.e., inductive and deductive reasoning, predictive and consistent experimental observations) frequently or occasionally (43-57%). I also discussed the nature of science with teachers during the focus group interview, though the discussion of PCK.

Science as Inquiry

	5 - Taught frequently	4 – Taught Occasionally	3 – Course or Prof Dev	2 – Some knowledge	1 –vague or unfamiliar
Concept, Principle or Theory					
Abilities Necessary to Do Scientific Inquiry					
Design and conduct scientific investigations	71%	29%	0%	0%	0%
Use technology and mathematics	71%	29%	0%	0%	0%
Computer based data acquisition	43%	0%	43%	14%	0%
Mathematical analysis and display	57%	0%	29%	14%	0%
Formulate and revise scientific explanations and models	29%	43%	29%	0%	0%
Recognize and analyze alternative explanations and models	29%	29%	29%	0%	14%
Communicate and defend scientific arguments	29%	71%	0%	0%	0%
Understandings About Scientific Inquiry					
Cumulative nature of scientific evidence	14%	71%	14%	0%	0%
Statistical variability the need for controlled tests	14%	71%	14%	0%	0%
Usefulness and limitations of models and theories	29%	57%	14%	0%	0%
Hypothesis and predictions	67%	33%	0%	0%	0%
Observations and evidence	71%	29%	0%	0%	0%

Table 3: Science as Inquiry Quantitative Data Analysis

Science and Technology (S&T)

	5 - Taught frequently	4 – Taught Occasionally	3 – Course or Prof Dev	2 – Some knowledge	1 –vague or unfamiliar
Concept, Principle or Theory					
Abilities of Technology Design					
Identify problem	14%	57%	14%	0%	14%
Choose between alternatives	14%	57%	14%	0%	14%
Proposing and demonstrating a solution	14%	57%	14%	0%	14%
Evaluating the solution and consequences	29%	43%	14%	0%	14%
Communicating problem, process, solution and consequences	29%	43%	14%	0%	14%
Understanding about science and technology					
Advances in one lead to advances in the other	29%	29%	14%	29%	0%
Different purposes and objectives for S & T	0%	57%	0%	43%	0%
Societal impacts and trade offs of technology	29%	29%	0%	43%	0%

Table 4: Science and Technology (S&T) Quantitative Data Analysis

Science in Personal and Social Perspectives

	5 - Taught frequently	4 – Taught Occasionally	3 – Course or Prof Dev	2 – Some knowledge	1 –vague or unfamiliar
Concept, Principle or Theory					
Personal and community health	14%	57%	0%	14%	14%
Population Growth	14%	43%	0%	29%	14%
Natural resources	29%	29%	29%	0%	14%
Environmental Quality	29%	29%	29%	0%	14%
Natural and human induced Hazards	14%	29%	29%	14%	14%
Science and Technology in Local, National and Global Challenges	14%	29%	14%	29%	14%

Table 5: Science in Personal and Social Perspectives Quantitative Data Analysis

History and Nature of Science

Concept, Principle or Theory	5 - Taught frequently	4 – Taught Occasionally	3 – Course or Prof Dev	2 – Some knowledge	1 –vague or unfamiliar
Science as a Human Endeavor					
Team verses Individual investigations and contributions	14%	57%	0%	29%	0%
Peer review, truthful reporting, and error acknowledgements and corrections	29%	43%	0%	14%	14%
Nature of Scientific Knowledge	29%	29%	14%	29%	0%
Study of natural world	29%	14%	14%	43%	0%
Inductive and deductive reasoning	0%	43%	14%	43%	0%
Evidence and skepticism	14%	43%	14%	29%	0%
Predictive and consistent with experimental observations	29%	29%	14%	29%	0%
Theories: useful but subject to change	29%	29%	14%	29%	0%

Table 6: History and Nature of Science Quantitative Data Analysis

Insights from the Case Studies: An Overview

The following sections present five case studies (Angela, John, Adam, Bridget, and Melissa) of the participants' experiences. They focus on the participant's individual responses to two sets of interview questions – one set completed at the start of the experience and the other at the end. The questions have been blended in the case study presentations. The focus group interview is discussed under the heading of Pedagogical Content Knowledge, as this emerged as the central focus of this discussion. The individual case studies pay particular attention to the participants' experience in the LSTPD program, consisting of a) their current work, b) their professional development background, c) their beliefs about professional development and professionalism (including what they see as good professional development, and their current needs), and d) their goals and reflections resulting from their participation. They are presented with lengthy quotes, as it is the belief of the researcher that these quotes best convey the participants' experiences. The discussion of the focus group study will illuminate some salient themes including teachers as learners and the requirements for learning. Final reflections from two participants will be presented in the summary.

The Case of Angela

Current Work in the LSTPD Program

Angela joined the LSTPD program in the summer of 2004. When she started at the lab, she was part of a special program through her school district where teachers were trained on energy and environmental energy technologies, specifically HVAC systems.

They would then use the curriculum they developed during their work at the lab to instruct students about HVAC systems in a partnership with a local college.

When Angela returned to the lab in the summer of 2005, she had left the school district that partnered with the lab for the HVAC project for another area district. Because of this she was unable to work on the same program, and was partnered with a scientist whose focus was on developing alternative energy sources. This scientist had a particular interest in bringing these sources to the poor African nations where electricity is not readily available, and generally very expensive.

Because of her work at the lab in 2005, Angela started a club at her school where she worked with students interested in aiding Africa through technology – specifically alternative energy development. She took three students to Ghana with her scientist to investigate what materials were readily available and could be used to produce energy.

Angela continued her work in the same research group in the summer of 2006. During this eight week research experience, Angela was asked to explore pickleweed as a source for biofuel.

Interviewer, Melissa (M): You've had lots of professional development. So tell me a bit about what you are doing this summer at the lab.

Angela (A): So he [her scientist] said to me, "Angela, I want you to do an outline for me. Here are the questions. How do we synthesize from pickleweed biofuel – a hydrocarbon? How would you teach that in your class and where would you begin?" He said, "I want you to do an outline for me." So I did you know, and I'm going – you gotta know about alkanes, and you gotta know about the esterification of this. So I'm writing it up and I've got this whole outline, and he

looks at it and says, “Oh, this is pretty good. But I want there to be a story. I need the kids to know why – that hook – why should they be concerned with synthesizing biofuels from vegetables?” And I go, OK. “So we’re going to come up with a story, and I’m going to meet with you later this week.” So, where you would go and buy a curriculum from [Lawrence Hall of Science], now we’re creating the curriculum. Ok, now how do we get kids to buy into this work that we want them to do? What are the components of that? And that’s what this [experience] has done - to do the research and say this is something I can use in the classroom (Interview, July 3, 2006).

Angela took another group of students to Africa at the end of the next school year with her scientist. In addition to working with biofuel, her scientist wanted the students to think about ways that hand-crank generators could be useful in Africa. To prepare Angela for this, her scientist sent her to meet other scientists at the lab with specialties in the area of LED light. Angela met with a variety of people who provided background for her questions, but then also encouraged her to engage with the information in the same way that we, as teachers, ask our students to engage with information that we teach.

(A): It’s empowering to know that you have a scientist, who may not know exactly what you’re talking about at the time, but maybe your subject is totally different from his, but he will say, “You know, I have somebody at the lab who knows this. Let me send you down to talk to this person.” Another thing we’re talking about dealing with are hand generated, hand cranked LED light system, and is that something we can introduce into a country like Eritrea, which is one of the other countries he’s working with. He didn’t have time to sit down and talk to

me about gears and cranks and torque and what all that means for building this light system, so he sent me over to [another scientist] who is this wonderful scientist here who just, basically unpacks everything I can use for my classes. And, not just connected to the hand crank, but also, “Angela, did I show you this thing that I have.” They’re just so willing and eager to give me everything. Or to teach me, or to show me, or give me another way of thinking about it. “Before you can even do this curriculum, let’s list the component of what you need to be able to explain to kids. And let’s educate you first so that you’ll be clear.” This is a different kind of professional development, different from other kinds of professional development. Sure, they’ll come in. They’ll teach you. But not to the depth, and not hold you to it. It’s like, they’ll teach it to you, but you know, if you do it or not.... Here, it’s like “Hey, I’m going to help you, but my help is conditional. You have to do some things to. You have to do a lot more things, because for me to tell you about it, you’re not learning by me telling you.” Just like with our kids right? The more we talk, the less they learn. Right (Interview, July 3, 2006)?

Angela would not be returning to the lab in the summer of 2007 because the program only provided for three summer experiences. She expressed a hope that she could still stay connected with her scientist in some way so that she can continue to develop curriculum and work with his projects in Africa.

Professional Development Background

Angela had an extensive professional development background prior to working with the LSTPD program. Her experiences in school-based professional development

mimicked those shared by other participants in this study, particularly the west coast teachers. They focused more on issues of literacy and classroom management, and less on developments in scientific phenomena. This was true of all participants in this study, as will be discussed in their case studies. Angela described her local professional development in the following way.

(M): So, LSTPD is this kind of a unique professional development program.

What's something in your own district that they would do for professional development? What would be a typical professional development day that you would go to for your district?

(A): One without science typically. We're probably more of a peripheral, oh, by the way, here's something from science. Literacy! How do we get kids to read? What are the strategies for building vocabulary? Decoding? That kind of stuff - things that we've been through before. Another one would probably be classroom management. Things that as a - you know, you don't really learn how to do classroom management until you're really in it. You can use all the strategies that you want, but until you are thrown into the trenches....

In Oakland we had more science. Science teachers from all of the different schools - high schools, middle schools, even elementary - they would separate us. But pretty much, um, on a semester basis, we would have professional development training in science on anything from assessment to new curriculum in the field. Teachers fine tune a new curriculum that they want you to investigate or use in your classroom (Interview, July 3, 2006).

When asked to discuss her professional development needs, Angela expressed that her needs are largely dependent on where she is in her career.

(M): So what do you think good professional development would be for you to kind of sustain you throughout your school year? What are the elements that you would see going into that?

(A): I think it would depend on where I am in the profession. I started involving myself – instead of making the choice at the time of offerings from the district – but seeking out professional development for myself. I started with the Exploratorium. Wonderful experience. Dynamic experience. It's very rewarding. They, what can I say, the professionals there are very humble. They are willing to work with you on every aspect. From classroom management to creating a module for your classroom. Building things for your class. Supplying you with the experience of using power tools to create things. They give you a mentor. They have a two-year beginning teachers program. And they don't just stop there. They continue to... when you become part of the alumni, you come back, and you do the same professional development with them. They keep up with you throughout the year. And it's wonderful to see them at all the national conferences, like the National Science Teachers' conference. They're there, and they know you, and they remember you, and they're happy to see you. And you get to engage with folks from all over the country – all over the world – come to their summer workshops that you're involved in.

So that was the first thing, and I needed that, because I was not very confident about teaching the subject. Oh sure, I know that content. But it's different when

you're in the classroom and you have to break this stuff down and make it very clear to kids. Because chemistry of itself is a phenomena. How do you make that phenomena – how do you disclose it, how do you unpack it – so that kids can see it and be successful? And the Exploratorium helped me do that. They gave me all of the – I wouldn't say tricks – but things that I needed. And continue to. You have access to their computers, to their scientists, to their professionals. They'll help with building things. I can go over there now and say, "I have a problem, can you help me with this?" And they say, "Ok, what's the problem. We can do that for you Angela." Just like that. Wonderful program. So that was good for me when I started. And they continue to provide support. Now, I'm at a different place. I've been teaching for a while. I've got the things from the Exploratorium. I know that resource is available to me. Now, how else do I grow as a professional (Interview, July 3, 2006)?

Beliefs about Professional Development and Professionalism

After discussing professional development experiences and background, Angela shared her own views on teaching as a profession, and the weight of considering teachers as professionals and offering them professional experiences. She noted that the general population may not understand the type of certification involved in becoming a teacher and maintaining your teaching license. She also noted that teachers are not as well-respected in the United States as in other countries. She feels that the LSTPD program allows her to feel more like a professional, in that it provides interaction between her and professional scientists currently engaged in the field. She also noted the luxury of

learning and working with professionals in the summer, when the demands of working with students are minimal.

(M): Sometimes I think the concept of being a teacher is looked at as something that's not very professional compared to other professions. First of all, what do you think about that? And secondly, how do you think LSTPD impacts you being a professional teacher, having a professional experience?

(A): I don't really think that people know that we have to be certified, that we have to be trained, that we have to have some mastery of some specialized area. And that defines what a profession is, and so a professional is someone who exemplifies the kind of, the qualities, of their profession. I'm a professional, and I have to be certified to do this thing. And a lot of it has to do with [the public's] experiences with teachers. I know the general population can sit up and say, "I know she's a great teacher," or, "I had a great this teacher, and a great that teacher." It still doesn't have the same weight as a lawyer, a CPA, a doctor, and it's a shame, because that's why we don't get paid. And you know, we are the starting place for all of these people. It's our motivation, it's our counseling that leads them to the profession, that produces the attorneys and what have you. I listen to students from the Philippines, from India, and they definitely value their teachers. They are just upheld. They have such high regard for teachers, but here, no. We're the floor mat.

I say I'm a teacher because this is my ministry. Everybody has one, and when you follow it, you get those opportunities that grow you in your profession, and that's what LSTPD has done. It's grown me in my profession. LSTPD has

allowed me to focus on myself as a professional. What do I need? What are some of the missing ingredients here? What are some of the things that I need to refine and master. And it's awakened me to the fact that, although I knew this, I need to continue to grow as a professional in order to not only stay on top of the technology and the science – and there's a lot of science out there. It's a humbling experience to come to the lab and say, "Wow, this is so much." But there are so many people here who are willing to give you what you need. And it's not like they're trying to make you become like this perfect, all knowing individual. They say, "Ok, you may not get this right now. Come back. Keep bothering me." It's wonderful to know that we have a community of folks who are willing to teach here. LSTPD has made me aware that there are people out there who are very concerned about the future of our children.

The leisure of learning, which you don't get during the regular academic school year. It's always rush, rush, and maybe I'll get to this later, and then maybe you forget about it. The leisure of sitting down and putting what you learned on paper so that it can be simplified and used with your students is a wonderful thing. And I think that's like, the biggest and the greatest part of this experience (Interview, July 3, 2006).

Connecting LSTPD to the Classroom Experience

One of the most important aspects of the LSTPD program is how the teacher plans to implement pieces of their experience as part of the curriculum. Before leaving the lab, teachers must write a professional development plan that lays out how the experience in Berkeley will translate into further professional development and classroom

instruction. They also create a lengthy Power Point presentation of their work and share this with the group. This presentation also should be transferrable to the classroom with some modification. Angela discussed how she has taken the experience back to her classroom based on her past summers at the lab. She noted that her own expanded understanding of these concepts has allowed her to provide context-based, inquiry lessons for her students. She is also engaging students with science literacy and vocabulary.

(M): So, how have you been able to take some of these things back just everyday into your classroom?

(A): We do a unit on energy. So when we first came to the lab, going back to my first year, I had never really given any thought to how they develop policies around energy standards. Oh, sure I knew about Energy Star appliances, and heard the commercials about how you can save and conserve. But, how do you know it's an energy efficient refrigerator. Well, from my experience at the lab, we began to look at what devices do they use to monitor. So, when you're talking to your kids, you start with, "Oh, do you know your parents are throwing away money?" And, "How much money is being lost on energy use products in your classroom?" Even the words, energy use products, it was something that I wouldn't have used – "How much money are your mom and dad losing on their refrigerator?" Now I can use energy use products in talking about your refrigerator. All the things that are loads on your electricity. It changes the way that you, that I, talk to my kids. And with that, it kind of encourages them now to think, not in lay terms, but more in scientific terms. A load. They're using a load, they're using energy use. They're taking about metering. Oh, how do we go

about metering a device? What are some other ways? Yeah, here's a way you can read a meter that's sitting outside your house, but another way that we can specifically determine how much energy is being used by our products. Here's another little device. Had I not come to the lab, I would not have known about that device. You know, unless I would have taken it upon myself and, "Oh, let me find out how they do this, right?" But from the experience here, I found out about a device called a kilowatt meter. Using that and watt meters, the kids can go and actually do their own investigations within your household. Which is a good thing, right?

So, it has given us, given me, another way of thinking about the tools for science. They're not just a scope or a beaker, all the traditional things. But, here's a tool I didn't even know about. So now I need to go look further. Like the hand-crank generator, they have on sale at Costco hand generated lights. This becomes a tool, this is technology and it also becomes a tool to get kids thinking about the number of cranks equals so much revolution of this big crank, equals how much power is generated from the number of revolutions. What about putting more on here? What if we load more LEDs on it? What if we put an LED, a bulb and a phone? A cell phone battery on it? What happens? How many.... Do you get more resistance with the cranking? These are the questions that I don't know the answer to, but I'll be investigating here this summer (Interview, July 3, 2006).

Goals and Reflections – Professional and Personal

A large component of the professional development plan (PDP) is describing your professional goals for using the information learned at the lab as part of your classroom

instruction. Additionally, teachers are given funds to purchase materials to help with that implementation, and to attend professional conferences during the academic year.

Angela has already made the LSTPD program part of her classroom instruction through her past experiences at the lab, but she articulated some of her current professional and personal goals. She included not only her curricular goals, but also goals for funding the projects that she started as a result of her work at the lab.

(M): Let's talk about the Professional Development, like the deliverables, the Professional Development Plan, the Power Point and what some of your goals were with the Professional Development Plan.

(A): My goals are very similar to that of last year. To stay in touch with my mentor, to speak out about things in terms of writing, getting money through grants for curriculum for our trip to Africa or for support materials for doing the work in Africa. Specifically, next year we are not going to be working with the refrigerators, we are going to be working synthesizing bio-fuel, looking at their resources, their seed plants. Well, I am doing the curriculum for it, so what activities can be infused in a lesson around bio-fuel. I guess any that we do around hydro-carbons. So, my other goal I guess which is slightly different is to get back to the lab, because this is my last year. Emphasis will be the grant money – to have the opportunity to have fun and come back up to the lab. So, I had three objectives this summer and all of them had to do with ultimately writing curriculum. One was coming up with an outline for teaching about bio-fuels and some activities. Then I had to do the thing around LED lighting. And finally, to finish up my project around refrigeration. My mentor wanted me think

of ideas, kind of look at a Power Point that I could present to the people of Ghana. And with that, the Power Point is supposed to serve as a vehicle to encourage the kids in a way to campaign around energy (Interview, August 3, 2006).

In addition to discussing her goals for her professional development plan, Angela shared her own personal reflections on being involved in this program and what it has meant in the context of her teaching. “I have tried my best to incorporate in my lesson and in my discussions a more global perspective for my kids. It is fortunate that I worked with a group that does international policy around energy. Before I came here I never thought of energy like money – expendable. And yet, whole governments are built and toppled and changed because of energy and access to energy. So it is very eye-opening. It is informing” (Interview, August 3, 2006).

Angela expressed that the program gave her validation as a science teacher, and allowed her to think more about her own professional development.

(M) : So have your views on teaching as a profession or the process of learning have they changed at all over the course of not just this summer even, but all of your summers?

(A): [My views on learning] have been validated - they say teachers are these long time learners, with the whole emphasis that we always need to go back to add onto our credentials. You don't have to sell me on this so much. Maybe now I will go to the Professional Development meetings at school and really pay attention and for that matter even say this is something that as a professional, I need. It is not just what we always get classroom management type of stuff. The new things, literacy, but maybe it could be done in a different way. Yeah, it

certainly has affected my understanding and my appreciation of being an educator (Interview, August 3, 2006).

Summary

The following table summarizes Angela’s dialogue:

<i>Participant</i>	<i>Work at the lab</i>	<i>PD Background</i>	<i>Beliefs about PD</i>	<i>Beliefs about Professionalism</i>	<i>LSTPD to Practice</i>	<i>Goals and Reflections</i>
Angela	Alternative energy for Africa.	Local – literacy based; Personal – local and national science organizations.	Career-dependent – earlier in career, needed everything; now seeking enrichment and social interaction.	People don’t understand certification; teachers in other countries get more respect; luxury of learning in LSTPD; we lead other professionals to their professions; she needs to continue to grow	Teaches units based on curriculum written at the lab.	Generate funding for student inquiry projects and taking student groups to Africa for energy research.

Table 7: Angela’s Interview Summary

The Case of John

Current Work in the LSTPD Program

John started working with the LSPTD program in the summer of 2004. Rather than work with a researcher in a lab, John worked under the program leadership to run a summer program for pre-service teachers (PST). His role is unique in that he facilitates their research experiences, and organizes workshops weekly. His role is more administrative than any other participant in the program. John is in the unique situation that he has worked at the lab for eight years and has had prior experience in research programs. John has continued his involvement with the PSTs since 2004 and works to

integrate them into professional meetings with the LSTPD teachers and others that might be working at the lab for the summer.

Professional Development Background

Most of John's professional development experiences come from his district or the Lawrence Berkeley Lab. His history at the lab spans much of his career, beginning in his third year as a teacher, in a program called the Integrated Science Partnership Project. Later, his district partnered with the lab for professional development endeavors. He was chosen to work with the high school research program on site, and later the pre-service teachers' program.

Interviewer, Melissa (M): So how did you first become involved in working out here at the lab?

John (J): It was my third year in teaching. They started a program called the Integrated Science Partnership Project – the ISPP. Around 10-15 years ago, there was a movement in research that showed students would learn better if they had every science every year rather than being compartmentalized. So a movement in science started where rather than teaching physical science in the 9th grade and biology in the 10th grade, that there would be an integrated science course, and some schools even went to four years of integrated science. So they found that there was a real need for support, content support, for the majority of biology teachers having to teach introductory physics and chemistry content. So, I think that's where that program started. And I worked in the ALS (Advanced Light Source) in a six-week research placement that year.

The next three years, we started a partnership just with my district to rewrite our curriculum. So then the lab focused on the Vallejo district. I worked on curriculum writing for the next couple of years for high schools. We had talks and lectures every day. And some people were in research positions, but half the group was writing curriculum and half were doing research. Then, the next year, I was supporting – we brought some elementary teachers from my district to the lab – so part of my time that year was in content area support for the elementary teachers. Then the next year I worked for the High School Student Research Participation Program – the HSSRP. And I was a mentor to the high school students. Then the year after that, I came on as a support for part of the PST program, which were mostly math majors that didn't have a lot of science background. So they created something called the Intensive Research Institute which had four two-week workshops that did various different areas and worked with a researcher. And I helped sort of pilot that program, and helped with some teachers, and helped the researchers teach a two-week workshop instead of having an intern. Then, after that I took over the entire PST program as part of my work with LSTPD. This year, I was also here as the IISME (Industry Initiatives for Science and Math Education) mentor (Interview, July 6, 2006).

In discussing his professional experiences in his district, John stated that most of what he encounters is pedagogical training. Like Angela, literacy has been the predominant issue for the district. His district also spends a great deal of time addressing curricular materials they have purchased from different educational groups.

(M): And would you say, in your own professional development in your district – is it content, or is it pedagogy, is it materials or...

(J): There's been a fair amount of literacy across the curriculum work – that's been the big buzz word. I'm the literacy coach for my school, so I get a lot of, learning different writing strategies and learning different reading strategies. I took some stuff that I learned here, brought it back to my district. In terms of reading strategies, and not a lot of content. A lot of our science department days, when we've had professional development days through the district – we've brought someone from the lab to give us content. I've maintained that partnership, although it's sort of dropped off a little bit. The only time we got content was stuff from the lab. The rest of the time was stuff about standards, stuff about testing, reading strategies. And I sit on the committee for my district that's in charge of professional development. Mostly what's happening now, being a state run school – we were taken over by the state for fiscal reasons – is a lot of – the emphasis is on the programs that they've bought and teaching people how to use the programs. Which is sort of not really pedagogy, because that would imply that they cared about us and how kids learn. This is more, "Thou shalt do this," and this is how this works. This is how we're going to make it fit. Which I think is where things are headed a little bit with the high school as well. They've purchased a book for us, which is against my best recommendations, they I think they purchased because it's the most scripted program that they think you can teach a section on genetics in biology in two weeks with one lab at the end.

Teacher says this and ask the students this. So, that's my next workshop that I've been invited to, and I'm probably not going to go (Interview, July 6, 2006).

Beliefs about Professional Development and Professionalism

John was eager to discuss what he viewed to be the differences between professional development experiences he had at the lab versus those he had in district-mandated experiences. The main difference is time – the LSTPD experience provides participants with time to be fully immersed in the experience.

(M): How does this compare, then, doing professional development like this, to professional development that you'd have in your own district? What does it look like and how does this compare to it?

(J): Well, the immersion is really the difference. I've never had a workshop during the school year that was a one day thing that comes close. AP training is a week long which is more extensive, but doesn't change your perspective on yourself as a professional as much. Doesn't really change your perspective on science and how science is done. Being immersed in a research laboratory like Berkeley lab – there's just so many things that you see and hear and talks and tours and being around and knowing what – and I learn so much now from all the people that I mentor and learning what they are doing in their projects, and helping them put together their presentations, that I probably get a broader experience of what's going on than anybody else (Interview, July 6, 2006).

John went on to discuss what he viewed to be contributing factors in making the Berkeley experience so exceptional. He began by discussing the fact that the LSTPD program brought together teachers from across the country to share their experiences both

in the lab, and in their home teaching districts. He also commented on the experience of feeling like an expert, and knowing that you are now part of a larger community of experts.

(M): So if you had to identify what components that you think make something good professional development, whether it's what's here at the lab or what's done in the district, just key things that you think are good components, what would you say they were?

(J): Getting outside of your experience is a good thing. Seeing, at least seeing how other districts and other teachers deal with their situation, and to see that no matter where you are in the country a lot of situations are the same, is a good experience. So I had some of that with the AP conference, and obviously here at Berkeley Lab I've interacted with people from all over the country. But I think getting outside of your experience as a teacher to see what you're teaching is really - it's been the most valuable thing to me. To feel like an expert. And now I feel like an expert not only in science but in science teaching, whether anybody respects that opinion or not, at least I feel like I know cutting edge science, and I know cutting edge scientists. And, I can have my students contact them, or I can bring them into my classroom. If you just stay within your own school, your own district, a lot of times the validity that you're doing doesn't really ever come true. It's just something that we're doing on our campus that isn't necessarily a worldwide thing. It doesn't necessarily change your image of yourself as a professional educator or a scientist (Interview, July 6, 2006).

Much like Angela, John's needs for professional development have changed over time, as his career has progressed. The current culture of high stakes testing has had a direct impact on his teaching. He commented that professional development, especially in the format provided by the lab, allows him to regain the sense of autonomy that standards and testing have quelled.

(M): So what do you think, or how do you think your needs for professional development have changed over the years, and what kinds of needs do you have now that you probably didn't have 11 years ago?

(J): Well there's the whole standards movement and the high stakes testing has been a big change within my career. When I started there were no standards. You know I was handed a class and they said, "You're teaching biology." So now, it's becoming very scripted and we're moving towards pacing guides – exact day by day, minute by minute expectations of what you're teaching. So the political context of everything is really driving professional development for me. When you don't have – when you're not sort of autonomous about what you're teaching... I can bring in my amazing lessons that I've developed at Berkeley Lab but if it's not in my pacing guide then I have to sort of be a rogue teacher and just do it. So, for me right now, it's trying to play that balancing act between where the district is pushing curriculum and where I know it should be. But this next year is going to be a big push as a leader in the professional development to try to maintain what I know – the inquiry based instruction that I know is the right way to teach science and that I know is the way that science is done. And I have 8 million sources to support me on that, but I just don't know where things are

going to go in this coming year and the next couple. But mostly the professional development will be about how to use this book to teach their program, which will be interesting. Maybe there are some things to learn from that. I'll try to keep an open mind (Interview, July 6, 2006).

John's comments on the current situation of teaching were expanded when he talked about his role and view on teaching as a profession, and himself as a professional. For John, the experience at Berkeley gives validity to his choices in the classroom. When he implements teaching strategies that can be seen as unconventional, he can validate his choices for those strategies by discussing his experiences at the lab, where "real" science is being done.

(M): So I only have one last idea and that's about professionalism. I think there's debate about teaching as a professional career or not. And, I guess the first part of the question would be, how do you envision teaching in the realm of professional careers, and what would you say to the idea that teaching is not a professional idea like being a lawyer or being a doctor, and then what do you think a program like this does for the idea of being a professional?

(J): Well, I think that there are teaching professionals and there are teaching unprofessionals. I think that unfortunately in this country in order to be a professional, you have to have respect from the outside, which we don't have. We have lip-service respect. "Oh, wow you guys teach science. That's got to be really hard. Those kids are really terrible now." That kind of stuff. And we have people in our profession that work very hard and who are very professional and are very well trained and who have kept up with every new piece of research in

their field in what they do. And then there are people who are just collecting a paycheck. And, there's everyone in between, including the ones who used to be very professional but have just grown tired because of the lack of respect. So I think that it's an amazingly complex problem to solve – teaching. And it takes someone that is willing to attack that problem. And anyone who hasn't done it can't really understand that it doesn't matter how long you've done it for, there's always something that's going to happen that you haven't foreseen or even conceived of. And you have to be able, on the fly, to get your students to where you want them to be, or where they need to be or at least get them some sort of understanding of the world. This program gives you, I think, outside validation. It's been for me. You know, I – when we were doing integrated science program, here I was, a kid from Berkeley, 23 years old, that is saying to people, “No, the old way of teaching this is wrong. We're going to do it this way. We don't have a book that goes along with it, and it seems infinitely disorganized. But it's actually the better way for your kids to learn science.” Then the year after that I come back from the lab, and I can say, “Well, this is curriculum that we developed at Berkeley National Laboratories,” And everyone says, “Oh.” And then, given the time to work things out and the time to acquire the new science and have the stories to inject and the confidence that the program gives me in myself and my background, I could let that out, and people really enjoyed that. It has made parent conferences a totally different experience. Instead of trying to apologize and convince them that this is something that was supported and good, or that I had any sort of business in standing in front of the classroom, I was

suddenly an expert. And that feeling and that knowledge that you are an expert makes you feel like a professional. And some people actually teach like that. I think that the concept of being a professional is – we have a long way to go. I think that having professional credentials – you’re required to have certification, we have advanced degrees, but the bottom line is there is not an inherent respect for public education. And until that changes, I don’t think we’re really going to be viewed as a profession (Interview, July 6, 2006).

Connecting LSTPD to the Classroom Experience

While John’s experience at the lab is quite different in that he is not working directly in a research lab, he is still able to take his experience back to the classroom and to his district. John is a leader in his district, and by his own description, this type of professional development is helping him develop his leadership skills to help promote good science teaching in his school. John is also responsible for creating a professional development plan, and receives the same funding for supplies and conferences as all of the participants. He hopes to implement some of the true-inquiry methods of open-ended projects in his teaching.

(M): So what about your Power Point? Are there aspects of your Power Point that you can use in your class, or is it more of ideas, just some of the ideas? I mean your experience is different, but...

(J): One of the things that I am trying to do is sort of re-connect my district with the lab more. We had a very big project in the late ‘90s and had a lot of participation going back and forth that really helped, but that sort of faded and probably half of those teachers, maybe more, are retired or have left the district

for other reasons. So we really have a group of science teachers that could really benefit from it.

I use the skills that I have developed with Power Point and I use the process of teaching people how to do the presentation. I spend a lot of time with PST teachers especially, but also teachers in making their Power Points. So I had my students do the same. So I have a lot of ideas about how to do that and how to give scientific presentations that I didn't have before doing this job and that has given me a chance to really hone my skills.

I always sort of leave their lab wanting to do open-ended projects. It always seems that I never just attack it. And I think, part of it, is that it's not just something that is easy to do at the beginning of the year when you have the energy to do it, and you know you get to February when the second semester starts and you might be starting something like that and you just fall flat cold. Part of it is that it's the kind of thing I see doing with the advanced kids. I know that is not necessary, but I see them getting more out of it and actually doing it in a way that is useful. The only kids that I have like that are the AP kids but the AP exam gets in the way. You don't have enough time after the exam to really develop a full on project and to do it before is just another time sink that they already don't have enough time to do what I am asking them, or they don't take enough time to do what I am asking them. It is just tough, and maybe I just need to do it with a low level group (Interview, August 8, 2006).

Goals and Reflections – Professional and Personal

John articulated his professional and personal goals in his professional development plan. His hopes are to increase the amount of technology he is using, and, more personally, to achieve National Board Certification.

(M): So your deliverables, like your Professional Development Plan, what are some of the goals that you set for yourself, whether it is the long term ones or the short term ones?

(J): Well, one aspect is to continue to increase the amount of technology that I use in my classes. I did a lot of chemistry experiments last year with probe-ware and that was my goal from last year. This year I am starting to teach biology so my goal is to bring my knowledge of probe-ware to my biology classes. I am also working district-wide on the science curriculum for true renovations of the curriculum. So we set a new course sequence last year and this year we are going to be working on the biology curriculum. We chose a new textbook for biology and then they chose a different one for us. So we are going to be adopting new textbooks for all of the classes this year. One sort of a long term goal I still have is the National Board Certification.

The equipment that I am buying is specifically for biology labs. Mostly oxygen and CO₂ sensors. It will be really nice. I am planning on working with [a scientist here] who studies global climate change and she is developing a data collection technique for her project which is actually geared towards middle school but I may use a lot of it because one of the new things that they are doing is reporting the data to a global website. So that the data that you do in the lab

actually is something that she is going to use for her research and other researchers have access to it as well. Which is pretty neat. Hopefully it will get kids more excited about doing labs and you know will open up a lot more discussions about how do we know this is good data and we need to make sure that it is good data because we are going to report it and it is going to be used, so there are different parameters.

I think one thing that I have maybe changed a little bit this summer is thinking about what is really important to teach and what in science specifically is really important. I think that there is a lot of stuff outside the science curriculum that I teach; there is no textbook for it and no written lesson plan. It comes down to you know, sort of intangible life lessons and things like that. You never have a kid come back five years later and go, “Wow that you really taught me Boyle’s Law so well.” That just doesn’t happen. “I am so glad I learned how to balance oxidation reduction reactions. Man that is invaluable to me.” But they come back and tell you some stuff, but maybe there are some other things that I can teach, not just to kids but to other teachers about the value of what scientists believe (Interview, August 8, 2006).

Summary

The following table summarizes John’s dialogue:

<i>Participant</i>	<i>Work at the lab</i>	<i>PD Background</i>	<i>Beliefs about PD</i>	<i>Beliefs about Professionalism</i>	<i>LSTPD to Practice</i>	<i>Goals and Reflections</i>
John	Oversees administration of certain summer programs at the lab	Local – literacy based; Personal – worked with the lab every summer for past 10-15 years (some as researcher, some as administrator)	Career-dependent – earlier in career, needed everything; now seeking collaboration – how do others do what we want to do?	Time to be fully immersed in the experience; LSTPD changed perspective on how science is done; validity – feeling like an expert; autonomy to make instructional choices; respect from outside the profession	Writes curriculum; does district training; wants to do more inquiry in the classroom; teach scientific method and safety in context.	Go further with inquiry and technology.

Table 8: John’s Interview Summary

The Case of Adam

Current Work in the LSTPD Program

Adam is in his second year with the LSTPD program. He is currently working in the Advanced Light Source (ALS) with the infrared microspectrometer, “trying to improve the ability for the microscope to see smaller images. To scan a larger region of a sample with more resolution” (Interview, July 10, 2006).. Adam came to teaching after several years in industry and is in a unique position to be able to work with some of the more advanced, technical research projects at the lab.

Professional Development Background

Adam entered teaching through a nine-month intensive university program in his home state. While enrolled, he participated in the Pre-Service Teaching (PST) program through the Department of Energy, designed for pre-service teachers, but not at the Berkeley location. Upon completion of that program, he applied to the LSTPD program.

Interviewer, Melissa (M): So, how did you first get involved with this program, the LSTPD program?

Adam (A): So I went to that PST program at Brookhaven. So, basically as soon as I read about it I wanted to do it. And I jumped into it because I love science and I didn't want – when I started teaching, I didn't want to lose my edge of newness. I didn't want to fall into being some old teacher who was just a teacher. I wanted to keep my engineering and thinking skills up while I taught. And I love doing research in science, so it was natural that I would give up my summers to do research. So anyway, I did the PST, and then after that, since I was already kind of inducted into the Department of Energy's system for teachers, I got a recommendation and heard about the LSTPD program through them, and that led me here (Interview, July 10, 2006).

Adam's first placement at the Berkeley lab was quite different than the research assignment he had in 2006. Given his unique background of working in the PST program, his assignment in 2006 was to run a portion of the PST program at Berkeley.

(A): Last year, I actually ran the intensive research institute group, which was six PSTs, but they were going to be math teachers. This was a program to get math teachers who were undergrads, who were coming from community colleges, going to four-year colleges. This was designed to get them exposure in the research setting. So, it was very light, not very technical. Although it was much more technical than they thought it would be, and they really had a hard time with that. They had four two-week seminars covering all kinds of different physics subjects at the lab and my job was to take some of the math and help them figure

things out, tie everything together, help them with their presentations (Interview, July 10, 2006).

Adam's home district does not offer professional development at the district-level. Teachers are encouraged to work with the local university on mentoring programs, and the state allows you to take days to attend workshops, but when asked if the district provided days where all science teachers attend meetings, he stated, "No, not at all." Given this, Adam's perception of the LSTPD program cannot be compared to anything the district offers. He noted when discussing this opportunity versus others, "It blows them out of the water. I mean, eight weeks. To ask any average teacher who possibly has a family, who has any other commitments, who has a life [at home] – to have them take their entire summer off, and devote themselves to a research program along with all the deliverables that go along with it – it's just above and beyond any professional development" (Interview, July 10, 2006).

Beliefs about Professional Development and Professionalism

Adam expressed a very clearly defined belief system about what makes a professional development experience worthwhile. He articulated the need for the information to be relevant to the classroom. He also felt that the experience should increase the content knowledge of the teacher.

(M): What do you think are – if you had to come up with what an ideal professional development plan is in your mind, what are some of the components that you could see it having?

(A): Number one, it's not even related to this research thing, but number one for professional development is that it should have at least one thing in it that you can

directly take and apply it in your classroom. Some little trick or tip or something – out of all the professional development stuff I’ve been to, the one thing that most teachers seem to like and appreciate from them is the tidbits that they can take directly with them in to the classroom and use. Not even an idea for a lesson, but the lesson plan, or the equipment, or tricks for classroom management, or whatever. Besides that, it should either improve the content knowledge of the teacher, or something obviously applicable. A lot of classes you take in education – I enjoy them because I like the sociology and the study of the kids and how the brain works – and those are all interesting. But when it comes down to it, they’re really at a level that’s hard to apply to teaching, so those courses I find less important. They may be interesting, but not very useful. Unless you’re good at that – unless they force you to come up with a lesson plan out of that – they force you to use it, I think that’s important. Unless you’re diligent enough to know how to just go write it and do it, but I think it helps if they actually force you to do it. Because otherwise, you’re just going to go do your teaching thing, and you’re going to get caught up in it and not have time to do it (Interview, July 10, 2006).

Adam’s professional development needs differ from all of the other participants in this study because he had an industry-based job before teaching. All other participants went directly into teaching as their first career experience. For that reason, Adam’s content and pedagogy experiences differ greatly from others in the program.

(M): So what do you think professional development, either out here, or what you do at home, could do to meet your needs, as a third-year science teacher?

(A): I'm strong with content. I actually would trade some of my content for the education – the ability to break subjects down more. So I love the professional development up there, and I'm of the personality where I already love science so I'm going to be really interested up there. I get a lot of science out of it. I think I could use more teaching stuff.... I don't want to downplay the importance of what you get out of the research because honestly, my job as a teacher is to teach students a bunch of stuff, and depending on what level you teach, what level class you teach, if you teach a higher level, you can assume that the students will some day be in a place where they will be exposed to technical people – scientists – or will become or need to know the skills to be a scientist. And if you've never seen or known a scientist yourself, than how can you teach it? So, just on the fact of the exposure of what goes on on a daily basis as a scientist is invaluable for lots of teachers (Interview, July 10, 2006).

Having been a professional in the industry world, Adam also was guarded in his discussion of whether teachers were professionals. He does not believe teachers are technically professionals because of their political status. But, behaviorally, he does consider himself a professional. He notes that if more teachers had jobs outside of teaching before engaging in this field, it may be easier for outsiders (parents, other professionals) to view teaching as a more substantive profession.

(A): The fact that I show up on time, the work ethic, how I conduct myself, the language I use every day in class. I try to model good citizenship. So in the teaching world, I guess that's what makes a professional. Competence, and I guess ethics. A professional does what he says and says what he does. He can

play the game, but doesn't abuse the game. It doesn't have to mean they are ambitious, or want to get ahead. They have to present themselves honestly and fairly to people.

I definitely think [LSTPD] gives me clout, but that's politics. I get clout because I went away and met a famous scientist and I've been in the science world, so my kids give me more credibility. The community gives me more clout because I'm in this program. I get an artificial kind of respect for that which helps if you're a new teacher. So, I think in general, it does help. [To get real respect] I think they would have to get out and be in, have jobs with a lot of responsibilities before they went to teach. To have jobs outside of teaching and then come back in. I think that would be the most effective, easiest way to make the profession of teaching professional (Interview, July 10, 2006).

Connecting LSTPD to the Classroom Experience

Adam's work in the ALS has triggered a desire to increase the amount of technology his students are using. Given the expense of technology, and the fact that his district is small, Adam hopes to purchase equipment like what he used at the lab, but on a far smaller scale, to be used in his classroom lab.

(M): That is really good. What are you hoping to use your money for in terms of the grant?

(A): I'm buying a spectrophotometer, which is a direct application of what I did this summer. Like spectroscopy. You can run reactive reactions, experiments and you put a small reacting reaction in one of those little square vials, (cuvette) put it in and map it over time. You can go away and another one will grow. Now

that is ideal. And then you could get the students to understand what that peak meant, when it disappeared and how it grew. That is an important big piece of it. I am also going to get a little fiber optics cable that you can point literally at the sun or the light source and directly instantly see the wave lengths of light that are coming from that. And so you can get to things like, you know electronic transitions and energy protons. It might be a little more advanced though (Interview, August 11, 2006).

Goals and Reflections – Professional and Personal

For Adam, the LSPTD program allowed him time to reflect on teaching. He expressed his interest in discussing his research experience with PSTs at his local university. His experiences in both the PST program and LSTPD program have influenced his belief that the most important thing you can do is reach pre-service teachers. Adam also feels there is a great need for providing collegial networks for teachers. Additionally, he feels that teachers of science must engage regularly with scientific phenomena and those directly involved with its creation.

(A): I am still forming my ideas on teaching too. I did a lot of thinking on that this summer. And of course being around other teachers and doing research every day, those ideas tend to bounce around in my head a lot more. So, you know, there is a lot more personal reflection on my styles of teaching. I really did not put that into my professional development plan. Last year's PDP actually I had put in various things. I really didn't change it. I am going to do the same things. It is less tangible to go and implement things in the classroom or the school. It is really hard to do that, I think. Except for specific presentations. I wanted to get

out and help encourage a more collegiate atmosphere than the other teachers. I think that is very important, to get out of our rooms and have a class with other teachers. And one of the best ways that I can do that is just go visit other teachers and talk to them. And say, this is what I am doing and have you tried this? So I guess personally, regardless of this place, one of the things I need to do is go out and even if it is just observe other teachers more. Just things that are good to do as teachers. Get out of your room and be with other teachers ... transfer ideas. So I put that in there. One of my really long term goals was to identify the logic trains that make a scientist a good scientist. Some of it has to do with developing communication skills in students. Some of it has to do with three-dimensional reasoning, being able to think through a process from what's going on and picturing it in your head and opening up areas inside the student's brain that allow them to do that. And so I am designing that into my PDP. I am not talking about all of these models you see for teaching science and even inquiry. Or if you look into inquiry in order to do inquiry the student has to do very focused types of skills that some students have and other students don't. So what are those skills that those students that have it have? Is conflict attainment? As far as like if you have to categorized information, departmentalize it. That is extremely important for interpreting data. So I have mentioned that in my PDP as well. I am sitting here analyzing data, and contemplating at the computer "what I am doing" and I go back to my teaching and I think well, okay I just figured that out, how did I figure that out. How did I draw on that data? How did I come up with that conclusion? So little bit by little bit over the summer I picked up little elements

about how I think about things. And then when my mentor comes and talks to me, of course he does it very readily. That is always in my head as far as how do scientists draw conclusions? And then I always relate that back to my students, or try. Of course I haven't formally come up with any lessons that really deal with that information. That has to be the next step (Interview, August 11, 2006).

When asked if he had any closing thoughts, Adam added, "I wouldn't have traded this opportunity for anything. Giving up my summer to do this was the best, it was fantastic. Because it is fun to do research and because it does invigorate me for next year. The program is completely worthwhile in ways that I don't know if you have completely pinpointed but it's a good thing" (Interview, August 11, 2006).

Summary

The following table summarizes Adam's dialogue:

<i>Participant</i>	<i>Work at the lab</i>	<i>PD Background</i>	<i>Beliefs about PD</i>	<i>Beliefs about Professionalism</i>	<i>LSTPD to Practice</i>	<i>Goals and Reflections</i>
Adam	Researching infrared microspectrometer in the ALS.	Local – none; Personal-participated in DOE's PST program, and LSTPD.	Must apply to classroom, improve content and/or pedagogy knowledge of the teacher.	Political status of teachers challenges notion of professionalism; behavior versus legitimate respect; having outside jobs first would increase notion of teachers as professionals	Increase access to technology.	Present to others in the district about what was learned; create logic trains about scientific thought.

Table 9: Adam's Interview Summary

The Case of Bridget

Current Work in the LSTPD Program

Bridget has a unique connection with the lab in that she first worked at the lab during the summer of 2004 on a voluntary basis. She applied for the LSTPD program for 2005, and spent eight weeks in a research placement. Her placement for the summer of 2006 was a four-week research placement, unlike any of the other participants in this study who were at the lab for eight weeks. She worked in environmental energy technologies, and the specialty of that group is LED lighting. Angela interacted with Bridget's scientist while studying LED lighting sources for Africa. Bridget's primary job was to take readings of LED's in variety of configurations. Ultimately, she created a presentation for her mentor that would both explain the science, and market the ideas and goals of their lab.

Interviewer, Melissa (M): So what did you accomplish at the end of the summer?

What was your end product in leaving your lab? It may not have been yours individually; it may have been what you were a part of that they worked on?

Bridget (B): My first product was a Power Point of a ton of different Power Points, and so my mentor had selected specific slides that he wanted put into a Power Point with specific comments on them for preview in getting investors and clients and stuff. He is retired from the lab but he still works there and has a company now that is going to be making LED lighting. So I put that together and that is kind of where I learned where LED lighting is going. Like okay, it is in my cell phone and it is in my street light, but where else is it now and then where is it

going. They make TVs out of it and TV monitors and you know using it for lighting a building or you know, street signs, whatever, all sorts of stuff.

I did some reading on how the LED voltage changed with the temperature of the overall system. I wrote up a lab report in a very traditional sense, you know, an intro, a purpose, a procedure, a data section and an analysis of when we went up to do the IR camera stuff. Why did we do it? What did we do? What did we learn? That sort of thing. So I did that, and I also wrote a procedural manual for using the goniometer for collecting data and then what do you do with the data; it's just a bunch of numbers so what do you do with those numbers to then get out how the light... what the goniometer does is it shows you what the light pattern would be like. And essentially you want a perfect circle so that it shows the same amount of light is going everywhere, and I took a ton of pictures both with the LED systems, the goniometer of the IR stuff and I learned how to like re-size them (Interview, August 4, 2006).

Professional Development Background

Bridget started work at the lab in the summer of 2003 after finishing her credentialing program for teaching. She worked in the atmospheric sciences division and gathered computer data for reports. She returned to the lab in the summer of 2004, and I happened to be placed in the same office for my first experience in the LSTPD program. Although she was not part of the program that summer, she attended meetings at my invitation, and in 2005 formally joined the program. She worked in atmospheric sciences for all three summers until 2006.

When discussing her district professional development, Bridget experienced what was mentioned by Angela and John: literacy. This could be due to the fact that they all teach in and around the Bay area in California.

(M): So why don't you tell me about a professional development experience that you might have in your own district?

(B): So in our district, four days before school starts, we have teacher work days. Three days are spent in workshops of various sorts. And then we also – every Wednesday, our kids get released at 1:50 and we go to a workshop at 2:10 that's 50 to 90 minutes long. And our school's really big on literacy, whether that's literacy involved in reading text, or – this year we're focused on math literacy, so we'll get together and we'll talk about strategies for literacy. We've also gotten together and talked about teaching students with special needs, whether that's with the special ed. department or teaching students foreign languages.

We have staff, not staff, department meetings. Some of those Wednesdays are used for department meetings, and this year in literacy, the Wednesdays that we spent, we spent them in departments, and there were six rotations, and we would rotate to go talk to somebody about, let's just say QAR [Question-Answer Relationships], and when we went to talk to the person about QAR, we talked about it in relationship to science text. But we don't have anything on science content, so much (Interview, July 19, 2006).

Beliefs about Professional Development and Professionalism

Given that Bridget is fairly new to teaching, her needs for professional development differ from Angela and Tom, who have been in the field for over ten years.

She echoes Adam in that she believes the professional development experiences should have relevance to her classroom experience. She also expressed a need for greater help with classroom management.

(M): So based on the experiences that you've had, both in your district and here, what do you think some qualities are that you would pinpoint to say, "This is what good professional development should have. It should have this, this, etc?"

(B): It should definitely have focus and purpose. And the purpose needs to be told to you, and it needs to be relevant. I've gone through some things at my district that are not focused or you're not sure what the relevance is. So I think that's one of the biggest things. And I think also, that the professional development needs to address a need. Whether it's to you specifically, so you go search out a program that fits your specific need, or the needs of your whole district, your department, or school. This year because I'm switching topics,[and my need is] curriculum development, as well as always, classroom management. That's always – I always think I could do better. I had a class this last year, my sixth period class. The beginning of the year, they were a nightmare. By April I couldn't wait to have them. But I would have liked that to have been November. So I would have liked some help with that (Interview, July 19, 2006).

Bridget's view of herself as a professional is much like Angela's. She feels that if doctors or lawyers are professionals, so too are those that provided them their education. She believes, like John, that working at a prestigious lab like the Berkeley Lab, adds credence to her message in the classroom.

(M): So tell me a little bit about a teacher as a professional. I think there's a lot of debate about whether teachers are professionals. Like, lawyers are professionals and doctors are professionals – how do you think teachers fit into the scope of that, and how do you think a program like the one we're involved in does for the concept of teachers as professionals?

(B): Well, without teachers, you're not going to have those other professions. You're not going to have doctors and lawyers and business men, and analysts. You have to have teachers. But I think that we're not seen that way. Very few people see a teacher as a professional. In essence you hang out with kids all day. Sure, we're there to help inspire and direct them but we're also there to give them knowledge they need to go further. College professors are seen as professionals, so why isn't the rest of the teaching world? And I think the LSTPD gives you that sort of, it gives you a pat on the back. And it kind of says, "You're going to spend four weeks, or eight weeks in a lab, where you are essentially the peers of these amazing scientists" (Interview, July 19, 2006).

Connecting LSTPD to the Classroom Experience

In general, those in charge of the LSTPD program try to fit a teacher's course load into their research placement. In other words, they attempt to place teachers in the biological sciences with researchers in the biological sciences, and so on. Bridget's teaching assignment changed over the summer; rather than teaching physical science and biology, she is going to be teaching earth and space science. She was unsure how she might adapt her experience into her curriculum. "Well, the LED part of my experience is not really huge in my earth science curriculum, but what I learned about infrared, what I

learned about safety is huge. And I can use the infrared part because we are going to talk about the electromagnetic spectrum” (Interview, August 4, 2006).

Bridget also hopes to make connections with her peers, much like Adam. “And I want to get more people aware of what options there are because the staff at [my school] are very young. So I want to get those people who are really excited and young to learn about all this stuff so that we can have a much better teaching staff. So my plan is to send out like a general e-mail to everybody explaining kind of what I have done and that not only is there a program LSTPD that they can apply to but that there are other programs on the planet for other areas” (Interview, August 4, 2006).

Goals and Reflections – Professional and Personal

Bridget’s goals, as outlined in her PDP are primarily to begin a graduate program in science education. She, like many young teachers, is eager to expand her content and pedagogy knowledge.

(M): So how do you think your role as a teacher, or your experience as a teacher has been enhanced as a result of your participation in the program? Are you able to take a lot of this back to your classroom and communicate it, or is it simply you having the knowledge and that gives you a confidence?

(B): I think the program gives me a lot of excitement. One, about being a teacher, two – about the kids, three- about the material. I must talk about the program, at least once a month. Oh, I learned this in the program, I learned that. We did this – I got this idea from here. I mention it all the time. I go back and I take all the lessons that are presented on Fridays and I share them with my department (Interview, July 19, 2006).

Summary

The following table summarizes Bridget’s dialogue:

<i>Participant</i>	<i>Work at the lab</i>	<i>PD Background</i>	<i>Beliefs about PD</i>	<i>Beliefs about Professionalism</i>	<i>LSTPD to Practice</i>	<i>Goals and Reflections</i>
Bridget	LED lighting; specifically for use in Africa	Local – some science, but largely literacy; Personal – worked at the lab prior to the program.	Must have a purpose, relevancy; must address a need.	Teachers should be respected like other professions since without them, there wouldn’t be other professions; need respect like college professors; LSTPD provides a “pat on the back”	Try to make connections between concepts at lab and in curriculum.	Share experience with others throughout the district.

Table 10: Bridget’s Interview Summary

The Case of Melissa

Current Work in the LSTPD Program

I entered the LSTPD program in the summer of 2004. I worked in the Environmental Technologies Division for six weeks. My primary project was to examine visibility data based on atmospheric conditions and parameters at national parks in Colorado and Wyoming. I took a sabbatical from the lab experience in 2005, but returned in the summer of 2006 for eight weeks in the same division. This expanse of time was spent researching transport phenomena for combustion modeling. Beginning in 2003, I taught an advanced placement course in environmental science. Given my degree and certification areas in chemistry, the leaders of the program at the lab saw a project in atmospheric chemistry as a good fit.

Professional Development Background

My professional development background is quite different from that of my colleagues in this study. I have been involved in a number of professional development experiences both inside and outside of my district. The county where I am employed offers two science-specific professional development days each year. There are a total of 11 professional days for teachers in a given school year. Some are allotted to classroom work, others to your school, and the rest to your curricular field. While none compare to the experience at Berkeley, they are generally formatted as a series of workshops with both in-house and outside presenters. Teachers may present on literacy, but it is tailored specifically to science. There is always a focus on standards and testing, but this seems to be true in most districts in the No Child Left Behind climate.

My experiences outside of my district include work with Johns Hopkins University's Materials Research division; Quarknet, a program run through Johns Hopkins University and FERMI lab; SENCER (Science Education for New Civic Engagements and Responsibilities) with Gettysburg College; and the College Board's intensive workshop for advanced placement teachers. While some of these experiences have been lab based, most centered on science pedagogy and discourse. All allowed me to learn a great deal about recent developments in science research.

Like my counterparts in the LSTPD program, I believe that my professional needs change with the advancement of my career. I, unlike Adam and Bridget, do not need as much time spent on lesson ideas or classroom management. Content-based experiences are of greater interest to me and fill a void that my district-professional development does

not have the time to fill. The experience of having time in the summer to grow professionally, uninterrupted by the demands of the classroom, is unparalleled.

Beliefs about Professional Development and Professionalism

My own personal bias as the researcher in the role of participant will be evident in my discussion of professionalism. I believe, like John, that there are teaching professionals, and those that bide their time, awaiting retirement. I think the lack of continuity, and the fact that teachers who do not perform at a certain level of quality are not released from their duties, provides constant challenges to the notion that teachers are professionals (a challenge faced in many professions in society, but few as public as the teacher). I am of the belief that because teachers receive college degrees and certifications, and must continually renew these certifications with courses and workshops, they have credence as professionals. It is our attitudes, in how we view ourselves and our role, which dictates whether the world sees us as professionals.

Being involved in the LSPTD program has, for me and for others, provided a much needed sense of credibility in our home schools. When I share with peers, administrators, parents, and students, the type of experiences I have been involved with at Berkeley, it greatly enhances their notion of me as a professional. The sheer mention of the words, “Berkeley” and “research” allows my constituents to view me as a competent, if not accelerated, professional in science education. Being involved in professional development endeavors, such as this one, are beneficial to the growth of the participant, and to the level of confidence of the stakeholders.

Connecting LSTPD to the Classroom Experience

I see connections between the LSTPD program and my own classroom experience in two ways. The first is content. Spending eight weeks at the lab provides a rich content experience, where I am immersed in a research project with experts in the field – people who make their living illuminating new scientific ideas. I thought it essential to take this content back to my classroom in some way. In teaching both chemistry and AP environmental science, I was able to make connections often to my research at the lab. When I taught about the atmosphere and the cycles of matter, I was able to engage students in my own work on atmospheric conditions on our nation's parks. When I discussed combustion in chemistry, I could explain how researchers are using models to create more efficient combustion tools and better fuels.

The second connection is the professional experience. I found the LSTPD program so engaging that I built a study around it – this study. I believe in good professional development, and how it can broaden the expertise of any teacher. This is good professional development, and all who participate feel enlightened and lucky. Rarely does a teacher feel lucky to do professional development, to spend weeks of their summer working. This is a unique experience, and I believe that if more partnerships like this were formed, and more teachers were reaching out to them, we could really have highly-qualified teachers.

Goals and Reflections – Professional and Personal

My professional goals, as outlined in my professional development plan (Appendix E), were largely centered on this research, and my future career aspirations. My primary goal was to complete my research study of the LSTPD program, and

ultimately my degree program. I requested funds to attend two professional conferences in my professional arena, and ultimately hoped to present at a professional conference. I hoped to, and ultimately did move into a new teaching role – one where I would instruct students on how to do college-level research, and facilitate research studies with the students spanning the academic year. I used some of my professional development funds to purchase literature and supplies that would support that endeavor. Much like Angela, the experience at the lab inspired to me to think what it means to educate, and about the impact a teacher has on students personally, as a community, and globally.

Summary

The following table summarizes Melissa’s dialogue:

<i>Participant</i>	<i>Work at the lab</i>	<i>PD Background</i>	<i>Beliefs about PD</i>	<i>Beliefs about Professionalism</i>	<i>LSTPD to Practice</i>	<i>Goals and Reflections</i>
Melissa	Physical/ Environmental Chemistry; Transport Phenomena.	Local – two curricular days/year; Personal – participated in a variety of self-selected activities.	Must do more than provide a lesson – must enhance knowledge; need more content, and leadership	Lack of continuity in teacher quality discredits the profession; Continues education, certification, and PD professionalizes teachers; teacher attitudes about the profession are important; LSTPD gives credibility	Able to teach content in chemistry and AP Environmental.	Present at a professional conference; earn degree; bring lab experience back to classroom.

Table 11: Melissa’s Interview Summary

Pedagogical Content Knowledge

Pedagogical content knowledge, as discussed earlier, was introduced by Shulman (1987) to further illuminate the concept that teachers possess a professional knowledge base that marries subject-specific knowledge with effective teaching. It is also suggested

in this study that PCK is a way of knowing science – that teachers can both share and grow knowledge through experiences that enhance their PCK. Without PCK, teachers would be unable to transform subject matter in a way that is comprehensible to others (Kennedy, 1998). Shulman (1987) described two dimensions of PCK: knowledge of research on students’ misconceptions, and knowledge of representations of subject matter.

Before entering into the focus group interview, the participants were introduced to the idea of PCK as a way of thinking about their craft, necessary for teaching science in the secondary school setting, and engaged in a discussion of what makes teaching unique from researching in science, and ultimately how teachers need to learn and interact with science in order to pass on that knowledge to their students. Three themes emerged as central to our discussion of PCK – knowledge of science content, knowledge of teaching science, and knowledge of resources.

Theme 1: Knowledge of Science Content

All of the participants shared a belief that science is more than a collection of unchanging facts. They emphasized the importance of knowing science in teaching science, and that the best way to know science is to do it. As John stated, “Doing science at the lab is a great model for how students should learn science and how to do science. They are doing science [at the Berkeley Lab] that hasn’t been done. They are using the scientific method” (Interview, July 26, 2006).

The teachers discussed their breadth and depth of knowledge as compared to those of the scientists. Many felt that they had breadth of knowledge, but not depth, including me.

We have to see how we can make connections in science. Working at the lab gives me perspective on how science is never really done in isolation. The biochemist may want to expose his assay to something in the Advanced Light Source, and have to depend on the physicist to get the data and interpret it.

Obviously, our depth of knowledge can't compare, but this experience shows how important it is to have a wide range of understanding science in a cross-curricular way (Melissa, Interview, July 26, 2006).

All of the teachers involved in this study have bachelor's degrees in content areas – biology, chemistry, and chemical engineering. All teachers felt this endowed them as highly qualified, especially John. "It gives me credibility. The fact that I went to UC Berkeley, and have a science degree, and come here and work in the summers – it gains me respect with kids and parents" (John, Interview, July 26, 2006).

Theme 2: Knowledge of Teaching Science

The participants shared what they believed to be essential components of teaching science – components unique to teachers. Adam expressed the importance of breaking down information into small details. Bridget talked about giving students the tools to not only understand but also to explain to others. John discussed alternative conceptions or "misconceptions" in his discourse and how through experiences students can learn to reevaluate their original ideas and learn how to apply that knowledge to new situations. I reiterated the importance of making connections across concepts, units, and other subjects, citing examples from work at the lab and in environmental science. Ultimately, everyone came to one conclusion – that teachers can adjust their approach to content through advanced understanding of pedagogy to meet the needs of all students.

I believe we need more mentoring for teachers by teachers. If you worked with a master teacher, and you knew your content, but weren't as sharp with pedagogy, team teaching or mentoring would really benefit you. The same goes for someone who has been in the profession. If they haven't been building their skills, get them into discussions with teachers who have – let them collaborate (John, Interview, July 26, 2006).

Another key feature for many of the teachers was their understanding of their student populations. All of the teachers, except for me, live in the same community where they teach (I had the experience of going through school in the community where I teach, which is unique from the other participants). All believed that having an understanding of their population further strengthened their ability to teach science.

The last prevalent theme in discussing the act of teaching science was knowing your goals, as well as the students' motivations. All agreed that contextual understanding of how science applied in the lives of their students was most important. Adam stated,

You're not just teaching physics, you're teaching students. What do they *need* to know? By the end of the year, what's *most* important? They all have different motivations – some are just getting through school, some love a subject, some already see the value in their lives, and other need you to show it to them. It makes me want to ask, 'Can I give them a way to see this is logical in every day life' (Interview, July 26, 2006).

Theme 3: Knowledge of Teaching Resources

While teachers agreed that their depth of knowledge could not compare to that of the researcher, they did express that teachers with PCK should have knowledge of

resources – how to get print, non-print, human, or technological sources– to teach different topics.

When you're a first year teacher, you're just trying to survive. People offer you suggestions, and you take them. After a few years, though, your program is your own. You've weeded out the stuff that didn't go well, and you're always on the prowl for really good lessons and materials. That's where the grant money is so useful – we do this not only to work in the lab, but to find more money for our classrooms (Melissa, Interview, July 26, 2006).

In their discussion of PCK, the participants addressed important standards associated with knowledge of science teaching (NRC, 1996, p. 62). This is represented in the table below.

Pedagogical Content Knowledge is the integration of content, curriculum, learning, teaching and students (NRC, 1996, p. 62).

Pedagogical Content Knowledge is the integration of content, curriculum, learning, teaching and students (NRC, 1996, p. 62).				
	Themes associated with the <i>National Science Education Standards</i> (NRC, 1996).	Engaging in inquiry on a continuous basis.	Tailor learning situations to the needs of students.	Utilize a broad repertoire of strategies.
Themes associated with participants' Discussion of PCK	<i>Knowledge of Science Content</i>	Science is more than unchanging facts - knowing science means doing science. Breadth over depth.		
	<i>Knowledge of Teaching Science</i>		Addressing alternative conceptions. Understanding the needs of a specific population. Knowing your goals for your students.	Breaking down information. Knowing tools that help explain content.
	<i>Knowledge of Resources</i>			Print, Non-Print, Human, and Technological Resources.

Table 12: Intersection of Themes Presented by the Participants and in the NSES

The concept of PCK, as discussed throughout this report, is that teachers have a unique way of both understanding and instructing science in the context of the classroom. This includes how they know science content, how they know science teaching, and finally, how they identify available resources. The NSES explicitly encourage teachers to engaged in inquiry regularly, situate learning, and draw from a broad repertoire of pedagogy. Where these intersect is of importance because it demonstrates how teachers are developing PCK in conjunction with the reform efforts in science education.

Summary

One theme that was prevalent in all discussions, and that shaped the study, was pedagogical content knowledge. At the onset, the study aimed to examine how participation in the LSTPD program impacted teachers' learning, and while this remained important throughout, much of the discussion hinged on the idea that teachers who consider themselves professionals should always engage in content-rich activities that they can shape into classroom experiences for their students. Hence, a main interest of the study shifted to include how professional development is impacted by and impacts teachers' PCK frameworks, and how they use these frameworks to bring high-level scientific experiences into high school classrooms.

All of the teachers in this study possess a willingness to grow professionally, learn current science and pedagogy, and engage in discourse about what makes their role in science education unique – their pedagogical content knowledge. While they arrived at teaching through different paths, found LSPTD through different means, and plan to engage their students in different ways, all would attest that they grew professionally as a result of the program. When asked whether he referenced his experience in his classroom, John summarized it best,

I definitely refer to my research experience, when teaching atomic and molecular structure, how spectroscopy works, the electromagnetic spectrum, when using curriculum I have developed [at the lab]. I also have students do projects that center around research done here at the lab. There have been several discoveries made here at Berkeley Lab not only over history, but in the last 10 years that I have been coming here. I make those connections to the standards that I am

teaching, either to the original discoveries, or to the current research that used the concept and extended it.

My whole concept of the scientific method has completely changed since working at the lab. The cumulative nature of science and the serendipity that plays a role in our understanding, and the way that technology goes hand in hand with extending our understanding of the universe - atomic structure and the electron microscopes, cosmology and the Hubble deep field, DNA sequencing at JGI and the human genome project. There are so many aspects of the development of scientific knowledge that scientists end up participating in other than just doing experiments; there are theorist, engineers, technicians, a whole team of people, who can do more and better science together rather than apart. In addition, the idea of "Big Science" also includes the idea of interdisciplinary work. The answers to our most important questions lie outside of the traditional fields and are somewhere in between (Interview, May 1, 2007).

Chapter 5: Summary, Significance, Implications, and Further Research

“Teacher expertise – what teachers know and can do – affects all the core tasks of teaching. What teachers understand about content and students shapes how judiciously they select from texts and other materials and how effectively they present material in class. Their skill in assessing their students’ progress also depends on how deeply they understand learning, and how well they can interpret students’ discussions and written work. No other intervention can make the difference that a knowledgeable, skillful teacher can make in the learning process” (Darling-Hammond, 1997, p. 8).

Overview

This study explored the influence of a content-based professional development program on the beliefs and practices of five secondary science teachers. In this chapter, the data presented in Chapter Four are compared to the initial research questions. A summary of the study is presented. The relationship between this professional development program and the review of literature will be discussed. Implications for this type of professional development program for science teachers are analyzed, in light of the findings. Finally, suggestions for further research are presented.

Findings from this study indicate that this type of professional development results in increased understanding of science content, research as a process, and the experiences of scientists. Teachers learned about more than their specific research

project – they learned about the interconnectedness of science research as a discipline. They learned that science is a living entity: growing and changing. In general, teachers were very positive about the experience of working in the lab, but it's important to note that it is a somewhat self-selected group in that all participants applied to work in the program, and returned to the lab for a second or third summer. Given the current reform needs of science education, the LSTPD program allowed teachers to experience inquiry first-hand, and think about ways of implementing such investigations into their classrooms. In addition to discussion about learning and professional experiences, teachers discussed PCK, as a group, and how they defined it through their training, context of their current teaching assignment, and their experiences working at the lab.

Teachers' views of practice were examined and their views of teaching as a profession (and ultimately, of themselves as professionals). Their participation in LSTPD had a tremendous impact on these views. All teachers indicated that work at the lab validated their authority in teaching science with students, parents, and other teachers. The LSTPD experience directly asks teachers to interact with content; through discussions in formalized weekly meetings, and more informal settings, teachers mapped how the content/research experience could translate into classroom practice. Teachers planned to implement this experience in a variety of ways in their teaching.

Summary of the Insights by Subquestion

The central research question explored how experience in an intensive content-based professional development program affected science teachers' learning, and how this in turn, affected classroom practice. This was examined through a series of sub-questions.

Subquestion 1: What is the impact of LSTPD on professional growth, as measured by the participant, in terms of their learning and pedagogical content knowledge?

The first sub-question asked how teacher learning and PCK were impacted by LSTPD. In this study, it was rationalized that the learning experiences gained through the LSTPD program were viewed in unique ways by the teachers – ways that are the result of their construction of pedagogical content knowledge. The science teachers in this study interacted with content in the context of pedagogy. In this program teachers are seeing new content, and often unpacking it in the same way that they would ask their students.

All teachers in this study were learners at some point in the professional development experience. Each worked on a project foreign to their typical professional experience of classroom teaching. As a result, all did extensive research about their project prior to beginning it, and throughout research. This was witnessed during observations of the participants' workspaces and examination of their lab manuals. Teachers in this study had varying strengths in content, as discussed somewhat in Chapter 4. Work in the field is what gave Adam confidence in his content abilities. For the rest of the participants, all of whom went directly into teaching after their college and certification experiences, the research at the lab was an opportunity to learn content firsthand.

The question then becomes how teachers analyze this learning through their understanding of PCK. The role of the Professional Development Plan is for teachers to think through how they will transfer the experiences they had at the lab into something

useful for their classrooms. Table 6 summarizes the participants' interview data and their demographic data. All of the participants have unique goals for the funding and experience they took away from the program. It is their personal, professional, prerogative to choose how the program will impact their classroom. Additionally, all participants created presentations that they shared with the program at large, and many, me included, use these presentations in the classroom.

	<i>Angela</i>	<i>John</i>	<i>Adam</i>	<i>Bridget</i>	<i>Melissa</i>
<i>Work at the lab</i>	Alternative energy for Africa.	Oversees administration of certain summer programs at the lab	Researching infrared micro-spectrometer in the ALS.	LED lighting; specifically for use in Africa	Physical/ Environmental Chemistry; Transport Phenomena.
<i>PD Background</i>	Local – literacy based; Personal – local and national science organizations	Local – literacy based; Personal – worked with the lab every summer for past 10-15 years (some as researcher, some as administrator)	Local – none; Personal- participated in DOE's PST program, and LSTPD.	Local – some science, but largely literacy; Personal – worked at the lab prior to the program.	Local – two curricular days/year; Personal – participated in a variety of self-selected activities.
<i>Beliefs about PD</i>	Career-dependent – earlier in career, needed everything; now seeking enrichment and social interaction.	Career-dependent – earlier in career, needed everything; now seeking collaboration – how do others do what we want to do?	Must apply to classroom; improve content and/or pedagogy knowledge of the teacher.	Must have a purpose, relevancy; must address a need.	Must do more than provide a lesson – must enhance knowledge; need more content, and leadership

	<i>Angela</i>	<i>John</i>	<i>Adam</i>	<i>Bridget</i>	<i>Melissa</i>
<i>Beliefs about Professionalism</i>	People don't understand certification; teachers in other countries get more respect; luxury of learning in LSTPD; we lead other professionals to their professions; she needs to continue to grow	Time to be fully immersed in the experience; LSTPD changed perspective on how science is done; validity – feeling like an expert; autonomy to make instructional choices; respect from outside the profession	Political status of teachers challenges notion of professionalism; behavior versus legitimate respect; having outside jobs first would increase notion of teachers as professionals	Teachers should be respected like other professions since without them, there wouldn't be other professions; need respect like college professors; LSTPD provides a “pat on the back”	Lack of continuity in teacher quality discredits the profession; Continues education, certification, and PD professionalizes teachers; teacher attitudes about the profession are important; LSTPD gives credibility
<i>LSTPD to Practice</i>	Teaches units based on curriculum written at the lab.	Writes curriculum; does district training; wants to do more inquiry in the classroom; teach scientific method and safety in context.	Increase access to technology.	Try to make connections between concepts at lab and in curriculum.	Able to teach content in chemistry and AP Environmental .
<i>Goals and Reflections</i>	Generate funding for student inquiry projects and taking student groups to Africa for energy research.	Go further with inquiry and technology.	Present to others in the district about what was learned; create logic trains about scientific thought.	Share experience with others throughout the district.	Present at a professional conference; earn degree; bring lab experience back to classroom.
<i>Teaching Years</i>	10	11	3	4	6
<i>Years in LSTPD</i>	3	3	2	2	2
<i>Students' Grade Levels</i>	9-12	10-12	11-12	9-10	10-12
<i>Subjects Taught</i>	Introducing to Physics, Biology, Physical Science	AP chemistry, chemistry, biology, integrated science, general science	Chemistry and Physics	Physical science, biology, earth science	Chemistry, AP Environmental Science, Introduction to Chemistry and Physics

Table 13: Summary of Participants' Interviews and Demographic Information

Subquestion 2: To what extent do science teachers in the program view professional development opportunities as enhancing their professional experience and expertise?

The second sub-question focused on the extent to which science teachers in the program view professional development as enhancing their experiences and expertise. To answer this, participants were asked to discuss what they viewed as good professional development based on their own needs, and how the LSTPD program held up against that vision. Participants were also asked to share how it compared to their previous professional development experiences, both in the district, and those sought out personally.

While there is some consensus among participants about what good professional development looks like, each participant expressed a unique need. Angela, John, and Adam all alluded to the fact that it is dependent on where you are in your career. Angela discussed this in terms of wanting more content experiences; John wanted to develop more leadership and camaraderie in his district; Adam wanted more pedagogy. Angela and John have each taught for ten or more years, while Adam had just finished his second. Bridget (who just finished her third year of teaching) and Adam both expressed that professional development should be relevant to the teacher, apply to the classroom, and address a need.

All participants were enthusiastic in their discussion of LSTPD as professional development. Angela discussed the leisure of learning under professional scientists in the summer. All participants echoed this at some point – that this experience surpassed any other professional development in which they participated. It is important to remember

that this group is somewhat self-selected. They all applied to be in the LSTPD program, were chosen, and were in their second or third summer of participation. They also volunteered for this study, further demonstrating their willingness to talk about the experience.

Discussion of professionalism was particularly important. All of the participants, in some sense, discussed how this program gave them credibility with their peers, districts, parents and students. Many also mentioned how the notion of teachers is challenged, either through their political status as “civil servants” to issue of “unprofessional” teachers who discredit the field (and while “unprofessionals” populate every field, teaching is in the public eye). Teachers need to model themselves as professionals through their behavior and experiences, but until those outside the profession regard teaching with greater respect, teachers will always feel the need to legitimize their work. Programs like LSTPD help teachers validate what they do and how they do it.

There seems to be no way to appropriately compare the LSTPD program to district-based professional development. Adam, for example, receives no professional development through his district. Angela and John work in districts where science is surpassed by literacy. Bridget’s district allots time regularly for professional development, but focuses it on pedagogy and asks that teachers think about how it can be applied to content. My experiences are from two full-day workshops during the school year – hardly a comparison in terms of breadth and depth when compared to LSTPD. I would suggest that the discontinuity found among all the teachers in regards to professional development in their district further necessitates participation in programs

like LSTPD. District leaders are slaves to many masters – they cannot devote the time and funding to a sustained program in the way that outside organizations (private or public) can.

Subquestion 3: How does the science teachers' view of classroom practice change after exposure to the Laboratory Science Teacher Professional Development program?

The third sub-question asked how the participants' view of classroom practice changed after exposure to the LSPTD program. It specifically asked teachers to focus on whether they would change their classroom habits and ideas, and if so, how. Angela's experience of taking students to Africa changed her outlook on teaching. While always someone that explored ways of reaching students, Angela's connection with the Africa energy research at the lab inspired her to create a club at her school, teach units on energy, and apply for grants to take students to Africa to gather data in the summer. John and I both expressed how working at the lab gave us a clearer picture of how knowledge in science is really created. John used the example of the scientific method – students have been taught this concept since their first experience with science in elementary school. The lab provides a living example of how researchers use the scientific method. Teaching it no longer becomes a rote experience, but rather an engaged inquiry. Adam planned to address the notion of science as a way of thinking with his students. All of the participants had goals of become leaders in their districts. LSTPD provided all of the participants with a context for how science is enacted as a living thing. Experiencing that firsthand inspired all of the teachers to take steps to bring science to life in their classrooms.

Significance of the Study by Category of Literature

The number and variety of studies focused on teacher learning, pedagogical content knowledge, teacher change, and professional development models are large when examined individually, but when looked at in tandem, the number drops dramatically. This study adds to that cross-section of research. In this study, five teachers' experiences in a professional development program were analyzed. Three important categories of knowledge emerged: a) the role of PCK in science teachers' understanding and assimilating information; b) LSTPD as a model of professional development; and c) the impact of professional development on teacher learning and teacher change.

Literature Category 1: The Role of PCK in Understanding and Assimilating Information

Participation in LSTPD increased teachers' confidence or self-efficacy (Bandura, 1986) to feel secure in their teaching. Experiencing science increased their content experiences and their pedagogical content knowledge - their ability to take their own conceptual understandings and transform them for student learning (Shulman, 1987). Teachers' PCK was enhanced as a result of their increased content knowledge and experiences. This is consistent with research findings that indicate that content understanding is prerequisite for PCK (Shulman, 1987; van Driel, Verloop, & deVos, 1998). According to Shulman, (1987), "To teach is to first understand. We ask that the teacher comprehend critically a set of ideas to be taught. We expect teachers to understand what they teach, and when possible, to understand it in several ways" (p. 14). These findings do not suggest that scientists do not have a PCK, as witnessed in Angela's interactions with her scientist. The data demonstrate that some teachers worked with

scientists who had more advanced understandings of science teaching classroom practice while other interviews provided no such evidence.

Justi and van Driel (2005) conducted a study with similar goals – to examine teacher’s learning and PCK in using modeling techniques in the classroom. They determined that in order to best enhance PCK, professional development activities should involve elements of their current teaching practice and connect to student learning. Additionally, activities that are proposed for the teachers in order to develop their knowledge should involve them in situations analogous to those that students may experience in their classes. Teachers should have opportunities to use their new knowledge in their classes and to investigate whether and how such knowledge contributes to their students' learning.

Seven categories of knowledge, theorized by Shulman (1987) were discussed in Chapter 2, and included, (1) content knowledge; (2) general pedagogical knowledge; (3) curriculum knowledge; (4) pedagogical content knowledge; (5) knowledge of learners and their characteristics; (6) knowledge of educational contexts; (7) knowledge of educational ends, purposes, and values. While Shulman did not clearly define each category, studies have addressed the complex nature of PCK in an effort to articulate its complexities (van Driel, et al. 1998; Loghran et al., 2004). Findings of this study indicate the participants share many of the components of PCK, and utilized them in thinking about how to transfer their professional development experiences into practice. These include a concern for expanding either their content or pedagogical knowledge, the importance of knowing their population of learners, and of knowing their school context, and finally their personal beliefs about teaching as a profession.

Literature Category 2: LSTPD as a Model of Professional Development

The Laboratory Science Teacher Professional Development program is designed to revitalize the research interests of science teachers, improve their content knowledge and scientific skills, and encourage the use of inquiry in their classrooms. Participants conduct supervised research and participate in professional development as a summer research associate. LSTPD provides teachers with professional, science, and technological research experiences through an eight-week summer research appointment at a Department of Energy Lab (specifically the Lawrence Berkeley Lab for this study). In addition, resources and scientific consultation are provided to the teacher for at least three years.

The LSTPD program embodies much of the research on effective design of professional development. In looking specifically at Supovitz and Turner's (2000) research, the program immerses its participants in inquiry, is intensive and sustained, focuses on subject-matter knowledge, and is grounded in national science standards. Loucks-Horsley and Stiles (2001) stated that professional development should allow for adult learning that will mirror the methods used with students, and building a community of learning among teachers.

I think where this program distinguishes itself from others highlighted in Chapter 2 is that at its core, the LSTPD program has as a key objective that teachers gain experience of doing authentic science research. While there are weekly meetings where teachers discuss pedagogy, this program is geared for those who want to increase their connection to what is currently happening in science. All of the participants in this study were directly engaged in the background research, experimentation, and data gathering

processes of a very real scientific endeavor. This was not a simulation where teachers were given a lab sheet to follow and a set of materials. This was a project that would continue after our eight weeks ended and we returned to our classrooms.

The framework for professional development discussed in Chapter 3 suggested that in order for professional development to be effective, it should include opportunities to interact with content, pedagogy, discourse, authentic experiences, inquiry, and assessment. The LSTPD program is a model that in some form or another provided opportunities in all of these areas. Teachers were researchers and had direct experiences with science content through doing science research. Through weekly meetings, and the professional development plan, teachers thought about their practice and instructional methods – pedagogy. The social nature of the lab – interacting with scientists in a variety of fields, and teachers from a variety of districts – allowed many opportunities for discourse, both formally (in pre-arranged meetings), or informally (over coffee or lunch). The experience was authentic – not a simulated lab situation that a teacher could “try out” before taking it back to his or her students. Teachers interacted with inquiry through their work with the scientists. Their own inquiry experiences, however, were not explored – a limitation of the experience. Finally, teachers were asked to assess their own experiences in their own way – what could they take back from the program to the classroom; how could the program have an impact on their practice; what support was needed to implement more authentic experiences with their students?

Other recent studies have examined the impact of similar professional development experiences on teachers’ subject matter knowledge and use of inquiry in the classroom (Akerson & Hanuscin, 2007; Ingvarson, Meiers, & Beavis, 2005; Johnson,

Kahle, & Fargo, 2007; Lotter, Harwood, & Bonner;2007). Lotter, Harwood, and Bonner (2007) examined the role of professional development leading to inquiry instruction in the classroom. They too focused on the importance of subject-matter knowledge and connections to pedagogy (Loucks-Horsley et al., 2003; Supovitz & Turner, 2000) in examining the impact of the program. Their program analysis examined a two-week summer research institute with three academic year workshops. The ultimate goal was to increase teachers' use of inquiry in the classroom. Teachers met for a morning inquiry workshop and afternoon lab experience at university research lab. Four conceptions were found to influence teachers' use of inquiry-based teaching: science (what science is, whether it is built on curiosity and is an active process), purpose of education (prepare students for life outside the classroom, a good work ethic, how to think, make them good citizens), students (passive learners to problem solvers), and effective teaching (can students apply their learning). In the end, not every teacher implemented inquiry into their classroom, but teachers viewed inquiry as a thinking process and this view was more clearly articulated after the professional development experience. All teachers came away with increased enthusiasm about incorporating inquiry into their classrooms, but enactment of inquiry varied. What does this mean for professional development? Teachers' knowledge and beliefs about science, the learning process, their students, and effective instruction influence the choices they make in their classrooms. The four core conceptions influence the type and amount of inquiry instruction performed in their classrooms. Only when teachers' conceptions align with goals of professional development or when teachers are dissatisfied do they change practice.

Equally as important is the spans of time in which the professional development program is enacted. Akerson and Hanuscin (2007) found that teachers successfully integrated reform initiatives in their science classrooms after a three-year professional development initiative in their school. Because their program spanned three years, teachers continued refining their practice over time and did not revert back to original practices, as is often the case in programs that end after one year (Barrow & Sawanakunanont, 1994 as cited in Akerson & Hanuscin, 2007). Four key elements sustained teachers in their program: monthly workshops, on-site support for individual teachers, length of time of the program, and the inclusion of teacher goals with researcher goals. Johnson, Kahle, and Fargo (2007) also noted the impact of a three-year program on student achievement. They found that students of science teachers who participate in professional development activities designed to increase the use of standards-based instructional practices demonstrate increased achievement in pre/post-unit assessments, specifically on state assessments. They noted, however, that such assessment data are not comparing the same students over time. This raises the question for all professional development endeavors – If students learn science through reform initiatives one year, and through traditional approaches the next, what will be the impact on their understanding of content?

Ingvarson, Meiers, and Beavis (2005) analyzed 40 different professional development programs using a cross-program analysis. Their results indicated that providing teachers with an opportunity to learn was the most important feature of any professional development program. The biggest impact on teacher knowledge was the extent to which the program focused on content. The largest impact on practice is the

extent to which the individual program provided opportunities for active learning and reflection on practice. Taken together, the significance of having a professional community was important and was largely influenced by time span of the program (amount of time program participants spent meeting with other participants).

If we accept that advancing teachers' expertise and knowledge of subject matter will have a significant impact on students' opportunities to learn and understand science through inquiry, then programs like LSTPD play an important role in creating opportunities to advance teachers' understandings of science (Loucks-Horsley & Matsumoto, 1999). AAAS identified the most important reason for professional development as allowing teachers to recognize the special expertise related to their work (1998). That expertise is as much pedagogy as it is content. The National Science Education Standards call for teachers to learn science content through inquiry, to integrate that knowledge into their current pedagogy, and to be lifelong learners (NRC, 1996). LSTPD is a model for reaching these goals.

These findings, however, problematize the recent movement to job-embedded professional development. Job-embedded professional development is a site-based or online experience that allows teachers to collaborate and reflect with peers in the same building or district. It is sustained over time, and connects to the teacher's classroom (Goodwin, 2005). While valuable in thinking about providing professional learning communities for teachers in the classroom, these experiences miss some of the key features expressed by teachers in this study, including the opportunity to be in a different setting, working with professionals in their content field, and having the luxury of uninterrupted time. Many districts are beginning to utilize job-embedded professional

development to both meet the immediate professional needs of teachers and provide a cost-effective way to implement staff development.

There is much to be learned about this issue. Increased attention to many forms of school-based, job-embedded professional development, including the deployment of staff to these activities is a promising example of improving professional development and reallocating resources. Myriad partnerships between districts and institutions of higher education reflect commitments to share responsibility for professional development and can represent frameworks for more efficient utilization of resources. At the same time, districts, institutions of higher education, and [state departments of education] may lack the expertise, time, and money to conduct rigorous evaluations of professional development to determine its full impact. District staff, teachers, and principals all struggle to find time for sustained, high-quality professional development and professional development may not always be carefully aligned with reform priorities or designed to meet teachers' professional learning needs (Grasmick, 2004).

There are, however, limitations to the LSTPD program not discussed explicitly by the participants. While participants were actively engaging in science research, the use of an inquiry model of investigation was limited to the scientists. That is to say that scientists were investigating phenomena with the aid of the teacher-researcher, but the teachers were not developing their own questions and following their own line of inquiry into research. Further, to understand how inquiry played a role in the scientist's work at the lab, the teachers would have to engage the researchers in conversations about why they chose to explore their particular topic.

Another limiting factor, logistical rather than theoretical, in this design is the time commitment required from the teacher. The program obviously requires half to all of the teacher's summer vacation. The dates are inflexible, which may limit some teachers' opportunity to participate. There is also an issue with asking teachers to commit such time over the course of three years. Some participants had to withdraw after two years simply because of personal life changes, like the birth of a child, or a wedding. While these participants were invited to return and finish their experience in the following summer, many were unable because of such commitments.

A final logistical issue encountered by those who travel from outside of the Bay area is the expense of living away from home for a sustained period of time. The Department of Energy provided a budget for housing, and a weekly stipend for the program. This was a set stipend for all participants working in labs around the country. The cost of living in a particular area was not a factor in determining the housing budget. The Bay area experiences a high cost of living, and suitable housing options were limited.

Literature Category 3: The Impact of Professional Development on Teacher Learning: Changing Practice

The ultimate aim of this study was to explore how the LSTPD program impacted teacher learning. What does it mean to learn? Even the simplest search for the meaning of "learning" provides a variety of classical theories – perceptual learning, cognitive development, classical conditioning, behavior modification, and social learning theory (Pressley & McCormick, 1995, pp. 145-177.) Teacher learning can be more specifically examined as change (Hueni, 1999). Teachers who are leaning are continually and actively constructing their views of education, see themselves as lifelong learners, and are

looking for ways to effectively transmit these same expectations to their students. They need to reevaluate their own value systems and be willing to challenge their existing frameworks (Fullan, 1993). This is the evolution of the field.

Crawford (2007) examined teacher learning through examination of knowledge and beliefs and the impact these had on use of inquiry methods. Her study followed the work of prospective teachers. She found that teachers' knowledge and beliefs were critical to creation of classrooms in which students develop understandings of how science is done in the "real world." Additionally, their knowledge of subject matter and pedagogy shaped how the teacher might respond to student questions and inquiries. Beliefs developed from personal experiences, inside and outside the classroom. For teachers to learn how to use inquiry in the classroom, they must first understand it. Part of the difficulty here is that researchers do not fully agree on what inquiry is. In her study, Crawford defined it as a set of interrelated processes by which scientists and students pose questions about the natural world and investigate phenomena. Inquiry is more than asking questions – it is a state of mind, inquisitiveness. The teacher moves beyond, "What is the name of that bird?" to "Are robins arriving in my backyard earlier each spring and why?" Crawford identified the most critical factor influencing intentions and abilities to teach science as inquiry is a teacher's complex set of personal beliefs about teaching and views of science. Teacher educators may model the design of inquiry-based lessons in methods courses, but it is not enough. It must be situated. Situated inquiry requires authentic contexts, activities, and assessments. This is important in understanding the role of a professional development program. Learning is situated in the context of conducting inquiry.

This study explored how a program based largely in content research could impact how teachers learned. There is no test of what was learned – only the hope that the research experiences had at the lab would translate into richer science teaching experiences in the classroom. All of the participants shared in their interviews what it meant for them to be involved in LSTPD and what their goals were for integrating what they learned. In discussions at the end of the school year following the data collection, John’s input summarized what everyone shared. He discussed four main points that were resonated by all participants: (1) having worked in a lab setting, and done research, we can relate how the lab work that are students conduct plays a role in the same discoveries that are made in Berkeley; (2) science is constantly growing and changing and we can discuss discoveries made at the lab during our time there; (3) the role of technology is enormously important in the progression of research; and (4) scientists do not work in isolation – it is an interdisciplinary effort, and we can ask our students to think about the interdisciplinary connections.

All of these teachers are, or aspire to be, leaders for others in their district (John’s Interview, August 8, 2006). In an era where collaboration is considered an important asset in teacher learning (Butler et al., 2004; Hawley & Valli, 1999; Lord, 1994), teacher leaders with strong content experience could be integral in helping others make the connections between content and pedagogy that are called for in the standards. Shulman (1987) states the importance of content knowledge in knowing how to teach science, “To teach is to first understand. We ask that the teacher comprehend critically a set of ideas to be taught. We expect teachers to understand what they teach, and when possible, to

understand it in several ways” (p. 14). This is the role that professional development, like LSTPD, can play.

Implications

The purpose of this study was to investigate the effects of a particular professional development program on teacher learning. The results demonstrated a significant effect on teacher learning as a result of the experience. The first important implication of this study is that it is wise for districts and outside organizations to invest in professional development experiences of this type for science teachers. Teaching and teachers must be recognized and valued for the tremendous role they play in the education of our children. It is essential that the status of the teaching career undergoes profound change in order to establish itself as a much more prestigious profession, attract motivated individuals to the profession, and to increase their retention in the profession. Professional development has the potential to improve the status of the profession. Additionally, it should help to make obvious the need to treat teachers as established professionals that deserve to be paid as any other highly-skilled professional. Because most teachers practicing today are products of nonreform-based preparation programs (Shymansky et al., 1997), partnerships between institutions of higher education or government agencies, and school districts, can assist in the development of these kinds of programs.

Further, the findings will assist present and future professional development providers in determining how to best meet the needs of science teachers in terms of deep content development. Even though one recognizes the important role of teachers in the success of the educational enterprise, there is clearly a gap between the reform goals and

the practices in place to translate them into reality (Lynch, 1997). Teachers are not given the chance to interact with reform based curricula such as the National Science Education Standards (NRC, 1996) and Project 2061 (AAAS, 1989). This program allows them to see what inquiry methods look like in practice – to understand that they are more than a notion of what good science looks like on paper; they are a way of practicing science.

Another significant variable that emerged was the importance of PCK. Fostering science teachers' pedagogical content knowledge (Shulman, 1987) appropriate to their curriculum area and population is one of the values that should guide professional development programs. Examples of such professional development might include modeling, coaching, or other active and classroom specific activities in which teachers can be facilitators and leaders; programs focused on local curricular goals or local populations; time during the school day for conversation and reflection; immersion experiences outside of the classroom; and different opportunities for teachers at different stages in their careers (Beller, 1998 as cited in Hueni, 1999). Providing teachers opportunities to experience reform-based curriculum enhanced the degree of reform-based activity they intended for their respective classrooms.

Finally, the duration of the program (eight weeks per summer over three summers) has also been referenced as contributing to its success both by the participants and in the literature (Lawrenz, 1984; Lynch, 1997). The longer the duration of the program the greater the chance that the teachers are engaged in learning and change. Time is necessary for teachers to reflect upon what they are learning, and to process and apply it in their own classrooms. Time is also necessary for them to share their experiences with their colleagues.

The conceptual framework for this study centered on the idea that teacher learning should be at the heart of professional development. Professional development has an impact on the “changes in teacher knowledge and practice, implementation of new programs, changes in school culture, and development of teachers’ leadership abilities” (Loucks-Horsley & Matsumoto, 1999).

Further Research

An area of further research on this topic would include the impact that this program has on students when secondary teachers convey their scientific endeavors. Specifically, what methods could science teachers use to communicate and enact scientific inquiry to their students? While it is nearly impossible to follow the progress of the same students in science over their teacher’s three years of involvement in LSTPD, it would prove interesting to uncover how their conceptions of science change over the course of one school year.

Another important issue for research would be a comparison between teachers opting for professional development of this type versus those who do not, and how they might integrate reform practices in their respective classrooms. One of the major concerns in this study is that the participants are somewhat self-selected. How do those that do not select professional development of this type and intensity relate current science practice to their students? Is it measurable? This also begs the question if teachers reach high levels of professionalism, how should they be compensated, commiserate with such attributes? If this compensation is not provided, what will sustain the professional workforce?

One final question for further research might be how to integrate experiences like this into district-based professional development. Not every science teacher is able to commit the time to an experience like LSTPD. How could they gain experience in real research settings? How can the school day or school year be structured to increase these types of interactions without asking teachers to do more than they feel they can? Additionally, how can funding be structured differently for professional development opportunities?

Professional development is context dependent, and this study is no different. There is nothing here that can be applied literally to all experiences, or all teachers. The success of professional development programs rests on the ability to adapt to the needs of teachers and current reform measures.

Conclusion

Research has been, and should be, conducted into the impact of professional development and student achievement, but this is not the only reason for teachers to participate in these experiences. If teachers are professionals, and I believe they are, they have an obligation to themselves, their districts, and their students, to engage in professional experiences that are aligned with science standards and benchmarks. All of the individuals in this study have science undergraduate degrees. All could have chosen to enter a scientific career. Ultimately, all chose teaching. That choice put them at a crossroads, where content met pedagogy. Learning how to navigate through the intersection of content and pedagogy requires support, mentorship, and professional development. The National Science Education Standards (1996) clearly outline goals for professional development that include learning science, learning how to teach science,

and learning to learn. The follow-up research presented in *Taking Science to Schools* (Duschl, Schweingruber, & Shouse, 2007), further specifies that in our current science teaching, students need a blend of inquiry and content, teacher-directed, and student led activities, and a connectedness of concepts across grade levels. The five teachers in this study invested two to three years (and sometimes more) of their lives to work at the lab. For some, like Adam and me, it required leaving home and family thousands of miles away for what was our entire summer break. All of this was done with the intention of reaching a certain acme in our knowledge and skills of science research.

Professional development for teachers should be analogous to professional development for other professionals. Becoming an effective science teacher is a continuous process that stretches from pre-service experiences in undergraduate years to the end of a professional career. Science has a rapidly changing knowledge base and expanding relevance to societal issues, and teachers will need ongoing opportunities to build their understanding and ability (NSES, 1996).

These teachers, and others like them in the program, were motivated because they understood that increased content knowledge would allow them to be more effective in the classroom. They learned and changed, and that is the ultimate hope for science teachers in an ever-changing world.

Appendix A: Self-Assessment Content Survey - Laboratory Science Teacher Professional Development Program. - Blank

Science as Inquiry

Concept, Principle or Theory	5 - Taught frequently	4 – Taught occasionally	3 – Course or Prof Dev	2 – Some knowledge	1 –vague or unfamiliar
Abilities Necessary to Do Scientific Inquiry					
Identify questions and concepts					
Design and conduct scientific investigations					
Use technology and mathematics					
Computer based data acquisition					
Mathematical analysis and display					
Graphing and charting					
Linear best fit analysis (Least Squares)					
Error analysis					
Formulate and revise scientific explanations and models					
Recognize and analyze alternative explanations and models					
Communicate and defend scientific arguments					
Understandings About Scientific Inquiry					
Cumulative nature of scientific evidence					
Historical influences on design and interpretation					
Statistical variability the need for controlled tests					
Usefulness and limitations of models and theories					
Hypothesis and predictions					
Accuracy and precision					
Observations and evidence					
Reporting methods and results					
Peer review and self correction					

Science and Technology (S&T)

Concept, Principle or Theory	5 – Taught frequently	4 – Taught occasionally	3 – Course or prof dev	2 – Some knowledge	1 – vague or unfamiliar
Abilities of Technology Design					
Identify problem					
Choose between alternatives					
Proposing and demonstrating a solution					
Evaluating the solution and consequences					
Communicating problem, process, solution and consequences					
Understanding about science and technology					
Advances in one lead to advances in the other					
Examples at Berkeley Lab					
Cyclotrons and Synchrotron					
Electron Microscopy and Scanning tunneling microscopy					
Positron Electron Tomography					
Synchrotron Light Sources					
Automated Supernova Searches					
Bubble Chamber and Particle Track Detectors					
Other Examples					
Polymerase Chain Reaction					
Supercomputers					
Transistors and integrated circuits					
Others?					
Others?					
Purpose and importance of patents					
Different purposes and objectives for S & T					
Societal impacts and trade offs of technology					

Science in Personal and Social Perspectives

Concept, Principle or Theory	5 - Taught frequently	4 – Taught occasionally	3 – Course or prof dev	2 – Some knowledge	1 – vague or unfamiliar
Personal and community health					
Population Growth					
Natural resources					
Environmental Quality					
Natural and human induced Hazards					
Science and Technology in Local, National and Global Challenges					
Green house gases and climate change					
Clorofluoro carbons and stratospheric ozone					
Nuclear Waste Storage					
Genetic Engineering					
Others?					

History and Nature of Science

Concept, Principle or Theory	5 - Taught frequently	4 – Taught occasionally	3 – Course or prof dev	2 – Some knowledge	1 – vague or unfamiliar
Science as a Human Endeavor					
Team versus Individual investigations and contributions					
Peer review, truthful reporting, and error acknowledgements and corrections					
Nature of Scientific Knowledge					
Study of natural world					
Inductive and deductive reasoning					
Evidence and skepticism					
Predictive and consistent with experimental observations					
Theories: useful but subject to change					
Historical Perspective (Berkeley Lab examples)					
Lawrence and the cyclotron					
Seaborg, plutonium and the periodic table					
Ghiorso and discovery of 12 elements					
Alvarez, and particle physics					
Calvin and photosynthesis					
Smoot and cosmic microwave background anisotropy					
Alvarez, Alvarez, Asaro and Micheal and iridium anomaly, mass extinctions					
Perlmutter, supernovas and dark energy					
Historical Perspective (Others)					

Appendix B: Self-Assessment Content Survey - Laboratory Science Teacher Professional Development Program. – Percentages

Science as Inquiry

	5 - Taught frequently	4 – Taught Occasionally	3 – Course or Prof Dev	2 – Some knowledge	1 –vague or unfamiliar
Concept, Principle or Theory					
Abilities Necessary to Do Scientific Inquiry					
Identify questions and concepts	71%	29%	0%	0%	0%
Design and conduct scientific investigations	71%	29%	0%	0%	0%
Use technology and mathematics	71%	29%	0%	0%	0%
Computer based data acquisition	43%	0%	43%	14%	0%
Mathematical analysis and display	57%	0%	29%	14%	0%
Graphing and charting	86%	0%	14%	0%	0%
Linear best fit analysis (Least Squares)	43%	14%	43%	0%	0%
Error analysis	14%	43%	43%	0%	0%
Formulate and revise scientific explanations and models	29%	43%	29%	0%	0%
Recognize and analyze alternative explanations and models	29%	29%	29%	0%	14%
Communicate and defend scientific arguments	29%	71%	0%	0%	0%
Understandings About Scientific Inquiry					
Cumulative nature of scientific evidence	14%	71%	14%	0%	0%
Historical influences on design and interpretation	14%	71%	14%	0%	0%
Statistical variability the need for controlled tests	14%	71%	14%	0%	0%
Usefulness and limitations of models and theories	29%	57%	14%	0%	0%
Hypothesis and predictions	67%	33%	0%	0%	0%
Accuracy and precision	57%	43%	0%	0%	0%
Observations and evidence	71%	29%	0%	0%	0%
Reporting methods and results	75%	25%	0%	0%	0%
Peer review and self correction	14%	57%	29%	0%	0%

Science and Technology (S&T)

	5 - Taught frequently	4 – Taught Occasionally	3 – Course or Prof Dev	2 – Some knowledge	1 –vague/unfamiliar
Concept, Principle or Theory					
Abilities of Technology Design					
Identify problem	14%	57%	14%	0%	14%
Choose between alternatives	14%	57%	14%	0%	14%
Proposing and demonstrating a solution	14%	57%	14%	0%	14%
Evaluating the solution and consequences	29%	43%	14%	0%	14%
Communicating problem, process, solution and consequences	29%	43%	14%	0%	14%
Understanding about science and technology					
Advances in one lead to advances in the other	29%	29%	14%	29%	0%
Examples at Berkeley Lab					
Cyclotrons and Synchrotron	0%	14%	14%	43%	29%
Electron Microscopy and Scanning tunneling microscopy	0%	29%	14%	29%	29%
Positron Electron Tomography	0%	14%	0%	29%	57%
Synchrotron Light Sources	0%	14%	0%	29%	57%
Automated Supernova Searches	0%	14%	0%	14%	71%
Bubble Chamber and Particle Track Detectors	0%	14%	14%	29%	43%
Other Examples					
Polymerase Chain Reaction	0%	14%	43%	0%	43%
Supercomputers	0%	0%	0%	14%	86%
Transistors and integrated circuits	0%	14%	14%	29%	43%
Others?	0%	0%	0%	0%	0%
Others?	0%	0%	0%	0%	0%
Purpose and importance of patents	0%	14%	14%	43%	29%
Different purposes and objectives for S & T	0%	57%	0%	43%	0%
Societal impacts and trade offs of technology	29%	29%	0%	43%	0%

Science in Personal and Social Perspectives

Concept, Principle or Theory	5 - Taught frequently	4 – Taught Occasionally	3 – Course or Prof Dev	2 – Some knowledge	1 –vague or unfamiliar
Personal and community health	14%	57%	0%	14%	14%
Population Growth	14%	43%	0%	29%	14%
Natural resources	29%	29%	29%	0%	14%
Environmental Quality	29%	29%	29%	0%	14%
Natural and human induced Hazards	14%	29%	29%	14%	14%
Science and Technology in Local, National and Global Challenges	14%	29%	14%	29%	14%
Green house gases and climate change	14%	43%	14%	29%	0%
Clorofluoro carbons and stratospheric ozone	29%	14%	29%	14%	14%
Nuclear Waste Storage	14%	14%	0%	57%	14%
Genetic Engineering	0%	29%	14%	43%	14%

History and Nature of Science

Concept, Principle or Theory	5 - Taught frequently	4 – Taught Occasionally	3 – Course or Prof Dev	2 – Some knowledge	1 –vague or unfamiliar
Science as a Human Endeavor					
Team verses Individual investigations and contributions	14%	57%	0%	29%	0%
Peer review, truthful reporting, and error acknowledgements and corrections	29%	43%	0%	14%	14%
Nature of Scientific Knowledge	29%	29%	14%	29%	0%
Study of natural world	29%	14%	14%	43%	0%
Inductive and deductive reasoning	0%	43%	14%	43%	0%
Evidence and skepticism	14%	43%	14%	29%	0%
Predictive and consistent with experimental observations	29%	29%	14%	29%	0%
Theories: useful but subject to change	29%	29%	14%	29%	0%
Historical Perspective (Berkeley Lab examples)					
Lawrence and the cyclotron	0%	0%	14%	29%	57%
Seaborg, plutonium and the periodic table	0%	14%	14%	14%	57%
Ghiorso and discovery of 12 elements	0%	0%	0%	29%	71%
Alvarez, and particle physics	0%	14%	0%	14%	71%
Calvin and photosynthesis	0%	14%	0%	0%	86%
Smoot and cosmic microwave background anisotropy	0%	14%	14%	0%	71%
Alvarez, Alvarez, Asaro and Micheal and iridium anomaly, mass extinctions	0%	14%	0%	0%	86%
Perlmutter, supernovas and dark energy	0%	14%	14%	0%	71%

Appendix C: National Science Education Standards (NRC, 1996)

PROFESSIONAL DEVELOPMENT STANDARD A:

Professional development for teachers of science requires learning essential science content through the perspectives and methods of inquiry. Science learning experiences for teachers must

- Involve teachers in actively investigating phenomena that can be studied scientifically, interpreting results, and making sense of findings consistent with currently accepted scientific understanding.
- Address issues, events, problems, or topics significant in science and of interest to participants.
- Introduce teachers to scientific literature, media, and technological resources that expand their science knowledge and their ability to access further knowledge.
- Build on the teacher's current science understanding, ability, and attitudes.
- Incorporate ongoing reflection on the process and outcomes of understanding science through inquiry.
- Encourage and support teachers in efforts to collaborate.

PROFESSIONAL DEVELOPMENT STANDARD B:

Professional development for teachers of science requires integrating knowledge of science, learning, pedagogy, and students; it also requires applying that knowledge to science teaching. Learning experiences for teachers of science must

- Connect and integrate all pertinent aspects of science and science education.
- Occur in a variety of places where effective science teaching can be illustrated and modeled, permitting teachers to struggle with real situations and expand their knowledge and skills in appropriate contexts.
- Address teachers' needs as learners and build on their current knowledge of science content, teaching, and learning.
- Use inquiry, reflection, interpretation of research, modeling, and guided practice to build understanding and skill in science teaching.

PROFESSIONAL DEVELOPMENT STANDARD C:

Professional development for teachers of science requires building understanding and ability for lifelong learning. Professional development activities must

- Provide regular, frequent opportunities for individual and collegial examination and reflection on classroom and institutional practice.
- Provide opportunities for teachers to receive feedback about their teaching and to understand, analyze, and apply that feedback to improve their practice.

- Provide opportunities for teachers to learn and use various tools and techniques for self-reflection and collegial reflection, such as peer coaching, portfolios, and journals.
- Support the sharing of teacher expertise by preparing and using mentors, teacher advisers, coaches, lead teachers, and resource teachers to provide professional development opportunities.
- Provide opportunities to know and have access to existing research and experiential knowledge.
- Provide opportunities to learn and use the skills of research to generate new knowledge about science and the teaching and learning of science.

PROFESSIONAL DEVELOPMENT STANDARD D:

Professional development programs for teachers of science must be coherent and integrated. Quality preservice and inservice programs are characterized by

- Clear, shared goals based on a vision of science learning, teaching, and teacher development congruent with the National Science Education Standards.
- Integration and coordination of the program components so that understanding and ability can be built over time, reinforced continuously, and practiced in a variety of situations.
- Options that recognize the developmental nature of teacher professional growth and individual and group interests, as well as the needs of teachers who have varying degrees of experience, professional expertise, and proficiency.
- Collaboration among the people involved in programs, including teachers, teacher educators, teacher unions, scientists, administrators, policy makers, members of professional and scientific organizations, parents, and business people, with clear respect for the perspectives and expertise of each.
- Recognition of the history, culture, and organization of the school environment.
- Continuous program assessment that captures the perspectives of all those involved, uses a variety of strategies, focuses on the process and effects of the program, and feeds directly into program improvement and evaluation.

Appendix D: The Author's Work Sample from 2004

Laboratory Science Teacher Professional Development Program Teacher Work Sample

Name: Melissa Cook

E-mail address: lissacook@comcast.net

DOE Lab for first summer: Berkeley Lab

Class: AP Environmental Science

Unit: Soil: Fertility, Agriculture, Pollution

Contextual Analysis:

Oakland Mills High School is located in Howard County, Maryland. Howard County Public Schools are highly regarded as being one of the top systems in the state. Additionally, there is tremendous wealth in the county, but it is highly concentrated in certain districts. Oakland Mills represents a more diverse environment, both racially and economically. The approximate population breakdown is 48% African American, 43% White non-Hispanic, 4% Hispanic, and 5% Asian and Middle Eastern. Additionally, Oakland Mills is home to many families of mixed cultures, meaning that students have parents from different racial or ethnic backgrounds. Oakland Mills is located in Columbia, MD, an area widely known by civil engineers and cultural anthropologists for James Rouse. Rouse, who designed Columbia as a planned community, envisioned an area where people of all socioeconomic backgrounds could live in the same communities. For this reason, a percentage of housing in all hamlets of Columbia is reserved for those receiving government subsidies. Oakland Mills is home to the largest number of students living in government subsidized housing and receiving federal aid. FARMS (free and reduced meals) data indicates that approximately 17% of students receive aid of this kind. While this number is strikingly low when compared to more urban environments, it is unusual given the culture and wealth of Howard County. For this reason, the school is unique.

Teaching in this environment is a unique and rewarding experience. As a graduate of the Howard County Public School System, I am constantly impressed with the drive for academic success. What I never understood as a student in a more homogenous school was the beauty of diversity within the county. Students at Oakland Mills cannot be neatly placed into cliques in the traditional sense. There is a community in the school that is echoed with students, parents, and teachers. Most students attended elementary and middle school together before entering Oakland Mills, and have come to know diversity in a way that cannot be appropriately described. They identify and understand differences, but never shun or disrespect as a result. This is not to suggest that this is a Utopian environment. Oakland Mills is fraught with problems, including a large struggling African-American male population, and disconcerting drop-out and attendance rates. The dedication demonstrated by those that work for and in that community helps to maintain balance.

As a teacher of science in Oakland Mills, I am constantly challenged to find what makes my students tick. In three years of teaching, I have amassed a protocol that works for me, but that is constantly changing. I consider my classroom a friendly but firm environment. I know each student personally – what they like to do in their free time, what they want to be, the subjects they enjoy and those they dislike, and often personal information that they feel comfortable sharing. At the same time, students understand that there are rules and guidelines. Because I teacher older students (juniors and seniors), the time to coddle has passed. My goal is to prepare them for what is to come – college, a career, the military, etc. I have a mantra, “If you didn’t get the grade you wanted, I didn’t get the work I wanted.” In reality, students are learning an important lesson – that life is only partly about what you know. The rest is how you play the game – can you complete something in a timely manner, are you dependable, can you seek help when you need it, etc.

I have taught three distinct levels of learners. The “lowest” tier would be those enrolled in Introduction to Chemistry and Physics (ICP). The next would be the Chemistry students. The final group is AP Environmental Science. While I modify some instruction for the students in my ICP class, I hold them to the same high expectations as I would my other classes. We often place a larger emphasis on the bigger picture of scientific study, and then add the details as evidence. For example, we discuss the plethora of uses of organic compounds, and then the chemistry behind them. In chemistry, context is equally important, but students are asked, in accordance with state and local standards, to learn very specific details behind chemistry. I feel that many tidbits of information throughout the twelve units are unnecessary at the high-school level. Given that many students will not remember the details after my class, I try to teach them in such a way that promotes other skills, like mental organization, analogy, and graphical representation. Stimulating other arenas of learning is equally important (if not more so) than ensuring that students understand each shred of material.

The focus of the AP Environmental class is slightly different (and a unit from this class will be discussed in this work sample). Because these students are taking a course for which they may be awarded college credit, it is extremely important to me that I prepare them for college work. As someone with a bachelor’s degree, master’s degree, and working on a doctorate degree, I feel that I can be of service in preparing these students for the rigors of college. I work with these students on enhancing the following skills: critical reading and writing, conducting scholarly research, defending an argument or thesis, completing inquiry based activities on an independent level, and becoming technology savvy. Students are often rudely awakened by the expectations of college professors in the arenas of research and writing. While they are reluctant at first to embrace these activities in science, they quickly learn that these are fundamental in all areas of academia.

Learning Goals:

Because I have chosen to discuss a unit in AP Environmental science, I am not able to address this topic as outlined. Because the chemistry course that I teach is

assessed at the local level, the objectives used in teaching that course are carefully designed (by teachers) to be developmentally appropriate and measurable in terms of student performance. They are also divided by subject matter and skills and processes (including reasoning ability). The AP Environmental Science curriculum is not examined by the state or local school boards, but is instead governed by the College Board, who designs the AP exam. If you would like to view the Chemistry objectives, please feel free to visit either www.howard.k12.md.us and click on the link “In the Classroom” or visit my personal webpage at www.scorpionchemistry.com and click on the link for objectives.

I have chosen to discuss the Environmental curriculum because it is more appropriate to the work I will be doing at the Berkeley lab. My next work sample will most likely draw from another course, such as Chemistry.

My learning goals for the AP Environmental Course are those set forth by the College Board. The following themes provide a foundation for the structure of the course:

1. Science is a process.
 - a. Science is a method of learning more about the world.
 - b. Science constantly changes the way we understand the world.
2. Energy conversions underlie all ecological processes.
 - a. Energy cannot be created; it must come from somewhere.
 - b. As Energy flows through systems, at each step more of it becomes unstable.
3. The Earth itself is one interconnected system.
 - a. Natural systems change over time and space.
 - b. Biogeochemical systems vary in ability to recover from disturbance.
4. Humans alter natural systems.
 - a. Humans have had an impact on the environment for millions of years.
 - b. Technology and population growth have enabled humans to increase both the rate and scale of their impact of the environment.
5. Environmental problems have a cultural and social context.
 - a. Understanding the role of cultural, social and economic factors is vital to the development of solutions.
6. Human survival depends on developing practices that will achieve sustainable systems.

The list of objectives for the entire AP course is extensive. For this reason, I will only list those relevant to the soil unit. The percentages indicate the portion of the AP exam that will be dedicated to that particular topic. Some information has been deleted as it was not relevant. The remainder of the course outline can be found at www.collegeboard.com or www.scorpionchemistry.com, then Objectives.

- I. Renewable and Nonrenewable Resources: Distribution, Ownership, Use Degradation (15%)
 - A. Minerals
 - B. Soils (Chapter 11)

1. soil types
2. erosion and conservation
- C. Biological (Chapter 13)
 1. natural areas
 2. genetic diversity
 3. food and other agricultural products
- D. Land (Chapter 14)
 1. residential and commercial
 2. agricultural and forestry
 3. recreational and wilderness
- II. Environmental Quality (20-25%)
 - A. Air/Water/Soil
 1. major pollutants
 - (i) types, such as SO₂, NO_x, and pesticides
 - (ii) measurement and units of measure such as ppm, pH, μg
 - (iii) point and nonpoint sources (domestic, industrial, agricultural)
 2. effects of pollutants on:
 - (i) aquatic systems
 - (ii) vegetation
 - (iii) natural features, buildings and structures
 - (iv) wildlife
 3. pollution reduction, remediation, and control

Maryland has no specific goals for environmental science as of yet. Maryland science curriculum is driven by the core learning goals. Goals are firmly established for Earth and Space Science, Biology, Chemistry, and Physics, but Environmental Science is still a draft document. All of these Core Learning Goals map to the Benchmarks for Science Literacy and the AAAS Standards. In accordance with federal and state curricular standards, Howard County develops its own curriculum. As of yet, no curricular program is developed for Environmental Science. All state core learning goals can be found at www.mdk12.org/mspp/high_school/what_will/science/index.html. The Environmental Science goals are as follows:

Goal 6 Environmental Science: The student will demonstrate the use of the scientific skills and processes (Core Learning Goal 1) and major environmental science concepts to understand the interrelationships of the natural world and to analyze environmental issues and their solutions.

Expectation 6.1: the student will explain how matter and energy move throughout the biosphere (lithosphere, hydrosphere, atmosphere and organisms).

Indicator 6.1.1: The student will demonstrate that matter cycles through and between living systems and the physical environment constantly being recombined in different ways.

At least: nitrogen cycle, carbon cycle, phosphorus cycle (rock/mineral), hydrologic cycle

Indicator 6.1.2: The student will analyze how the transfer of energy between atmosphere, land masses, and oceans results in areas of different temperatures and densities that produce weather patterns and establish climate zones around the earth.

At least: differential heating and cooling, oceanic and atmospheric circulation patterns, climates and microclimates, biomes.

Expectation 6.2: The student will investigate the interdependence of organisms within their biotic environment.

Indicator 6.2.1: The student will explain how organisms are linked by the transfer and transformation of matter and energy at the ecosystem level.

At least: photosynthesis/respiration, producers, consumers, decomposers, trophic levels, pyramid of energy/pyramid of biomes.

Indicator 6.2.2: The student will explain why interrelationships and interdependencies of organisms contribute to the dynamics of ecosystems.

At least: interspecific and intraspecific competition, niche, cycling of materials among organisms, equilibrium/cyclic fluctuations, dynamics of disturbance and recovery, succession (aquatic and terrestrial)

Indicator 6.2.3: The student will conclude that populations grow or decline due to a variety of factors.

At least: linear/exponential growth, carrying capacity/limiting factors, species specific reproductive factors (such as birth rate, fertility rate), factors unique to the human population (medical, agricultural, cultural), immigration/emigration, introduced species.

Indicator 6.2.4: The student will provide examples and evidence showing that natural selection leads to organisms that are well suited for survival in particular environments.

At least: coevolutionary relationship, e.g. symbiotic relationships, variation within a species increases survival potential, natural selection provides a mechanism for evolution, adaptations of organisms within biomes.

Expectation 6.3: The student will analyze the relationships between humans and the earth's resources.

Indicator 6.3.1: The student will evaluate the interrelationships between humans and air quality.

At least: ozone, greenhouse gases, volatile organic compounds (smog), acid rain, indoor air, human health.

Indicator 6.3.2: The student will evaluate the interrelationship between humans and water quality.

At least: fresh water supply, point source/nonpoint source pollution, waste water treatment, thermal pollution, Chesapeake Bay and its watershed, eutrophication, human health

Indicator 6.3.3: The student will evaluate the interrelationships between humans and land resources.

At least: wetlands, soil conservation, mining, solid waste management, land use planning, human health.

Indicator 6.3.4: The student will evaluate the interrelationships between humans and biological resources.

At least: food production/agriculture, forest and wildlife resources, species diversity/genetic resources, integrated pest management, human health

Indicator 6.3.5: The student will evaluate the interrelationships between humans and energy resources.

At least: renewable, nonrenewable, human health

Expectation 6.4: The student will develop and apply knowledge and skills gained from an environmental issue investigation to an action project which protects and sustains the environment.

Indicator 6.4.1: The student will identify an environmental issue and formulate related research questions

At least: writing letters, performing a literature search, using the internet, interviewing experts.

Indicator 6.4.2: The student will design and conduct the research.

At least: field or laboratory, questionnaire/opinionnaire

Indicator 6.4.3: The student will interpret the findings to draw conclusions and make recommendations to help resolve the issue

Indicator 6.4.4: The student will apply the conclusions to develop and implement an action project.

At least: physical action, persuasion, consumer action, political action

Indicator 6.3.5: The student will analyze the effectiveness of the action project in terms of achieving the desired outcomes.

Assessment Plan:

Types of Assessments	Learning Objectives	Format of Assessment	Modifications (if needed)
1. Pre Assessment	Science is a process. Science is a method of learning more about the world. Science constantly changes the way we understand the world.	Discussion – What is soil? Who studies soil and why? What types of tests might you run to examine the quality of soil?	Students might be asked to summarize in written or pictorial format, the discussion, so that those who are not oral learners may participate.
2. Formative Assessment	Renewable and Nonrenewable Resources: Distribution, Ownership, Use	Research a vitamin or mineral and find specific information.	Students who may not have access to a computer may submit the

	Degradation (15%) -Minerals		assignment through other means.
3. Formative Assessment	Renewable and Nonrenewable Resources: Distribution, Ownership, Use Degradation (15%) -Soils (Chapter 11) -soil types -erosion and conservation Environmental Quality (20-25%) -Air/Water/Soil -major pollutants types, such as SO ₂ , NO _x , and pesticides -measurement and units of measure such as ppm, pH, µg -point and nonpoint sources (domestic, industrial, agricultural)	Several labs will be completed during the unit, including measures of turbidity and soil quality.	Because labs will be run in class, students do not need to fear not having access to materials. Students who might prefer group or individual work could also be accommodated.
4. Formative Assessment	Renewable and Nonrenewable Resources: Distribution, Ownership, Use Degradation (15%) -Biological (Chapter 13) -natural areas -genetic diversity -food and other agricultural products -Land (Chapter 14) -residential and commercial -agricultural and forestry -recreational and wilderness Environmental Quality (20-25%) -Air/Water/Soil -major pollutants types, such as SO ₂ , NO _x , and pesticides -measurement and units	Sedimentation and Runoff Webquest	Students may work individually or in pairs as they see fit. Students can handwrite or type answers to webquest questions.

	of measure such as ppm, pH, μg -point and nonpoint sources (domestic, industrial, agricultural) -effects of pollutants on: -aquatic systems -vegetation -natural features, buildings and structures -wildlife -pollution reduction, remediation, and control		
5. Post Assessment	All objectives tested.	Formal test for the soil unit.	Students are entitled to extra time as needed.

It is important for students to be exposed to a wide variety of assessment types. Students often view assessment as simply a quiz or test, but it is instead, a way for them to gauge their own learning and for me to gauge their progress. Discussion is a good way to get students engaged and thinking about a topic. It allows them to voice an opinion, which most students desire. At the same time, they can feed off of each other and begin organizing their thoughts around a topic. I often have students individually contribute to activities that are designed more as background material, simply because it allows them to take on a new a different task. Students are generally asked to identify every tidbit of information in a particular unit. At times, that is unnecessary, as in the vitamins and minerals activity. Each student has a common assignment but a unique topic. They come together to make one large course assignment that everyone can later use as reference material. Labs are essential and fundamental in science learning. Students, whether they plan to follow a course of study in science or not, should be exposed to scientific investigation. Labs, while structured, allow students to do some exploration on their own. Additionally, the lab report teaches students how to organize data in a fundamental and logical fashion. A webquest is a good way to engage students in something they already like to do – surf the internet. While this webquest is structured, it still provides students with “online” time to gather data. Often, seeing information in a text and in notes becomes mind-numbing. A webquest provides a new and different format. Formal tests in this class consist of multiple choice questions and free response questions. This is due to the format of the AP exam.

I believe my test is a valid predictor of my students’ abilities. Although it is often suggested that a teacher “backward map” the curriculum, I tend to avoid making the assessment until the instruction is near conclusion. I can be assured that I am testing information that students learned. Some questions may be stated in unfamiliar ways, but this is in preparation for the AP exam, where questions about a familiar topic may be asked through unfamiliar means. I obtain questions from old AP exams, AP study

guides, and supplemental text materials. One method I hope to use in the future is asking students to design AP questions.

Implementation Design:

Instructional Activity	Learning Objectives	Resources	Time Frame	Assessment
A. Position Journal – assigned at the start of each unit; includes a discussion of recently published work on the topic.	III. Renewable and Nonrenewable Resources: Distribution, Ownership, Use Degradation (15%) A. Minerals B. Soils (Chapter	Scholarly Journals found at the library or online, and some, select, websites	Generally 3-4 weeks for each.	Based on a well-developed thesis, argument supported by research, and overall presentation .
B. Textbook chapter Power Points distributed – Students complete work on power point based on reading of chapter (11, 12, 14)	11) 1. soil types 2. erosion and conservation C. Biological (Chapter 13) 1. natural areas 2. genetic diversity	Students learn general note-taking and organizational skills through the use of their text and in-class lecture.	Generally 3-4 class periods to complete in class. What is not completed in class will be completed at home.	Assessed during the unit test.
C. Study Guide – a study guide is distributed for each chapter studied.	3. food and other agricultural products D. Land (Chapter 14) 1. residential and commercial 2. agricultural and forestry 3. recreational	Textbook and classroom notes.	Students are given the study guide at the start of the unit and may submit it for 10% bonus on their test the date of the test.	Graded as 10% bonus on the test (which is 40% of their overall grade).

<p>D. Vitamins and Minerals Project – students are asked to use Microsoft Word to create a table that outlines their assigned vitamin or mineral, its common name, source, deficiency disease, and the characteristics.</p>	<p>and wilderness IV. Environmental Quality (20-25%) A. Air/Water/Soil 1. major pollutants (i) types, such as SO₂, NO_x, and pesticides (ii) measurement and units of measure such as ppm, pH, µg (iii) point and nonpoint sources (domestic, industrial, agricultural) 2. effects of pollutants on: (i) aquatic systems (ii) vegetation (iii) natural features, buildings and structures (iv) wildlife 3. pollution reduction, remediation, and</p>	<p>Students may use whatever materials they see fit, including the internet. As with all assignments, students are asked to document their sources.</p>	<p>Generally 1-2 class periods. The assignment is to be completed at home and e-mailed to me. I assemble it into one large document.</p>	<p>If students complete the assignment in a thorough manner, full credit is awarded.</p>
<p>E. Labs – Three labs are assigned over the course of the unit: (1) Soil Management, (2) Potting Experiment, (3) Soil Turbidity.</p>	<p>and units of measure such as ppm, pH, µg (iii) point and nonpoint sources (domestic, industrial, agricultural) 2. effects of pollutants on: (i) aquatic systems (ii) vegetation (iii) natural features, buildings and structures (iv) wildlife 3. pollution reduction, remediation, and</p>	<p>Students are provided all necessary resources for the completion of the labs. The Potting Experiment lab is self-designed and run by the students and fewer guidelines are provided.</p>	<p>Students are generally given one class period (90 minutes) to complete each lab. The potting lab is one that can be completed and monitored at home throughout the unit.</p>	<p>Labs are graded for the quality of data collected and the cohesiveness of the lab report. If insufficient data is collected, students may still earn credit for explaining the facets of the experiment that went awry.</p>

<p>F. Sedimentation and Runoff Webquest – students use the internet to explore information about sedimentation and runoff.</p>	<p>control</p> <p>Science is a process.</p> <p>Science is a method of learning more about the world.</p> <p>Science constantly changes the way we understand the world.</p>	<p>Students are to use websites provided in the instructions for the webquest. If a student feels that the website provided does not thoroughly address the topic, they may search elsewhere.</p>	<p>Students work in pairs to complete this assignment and can generally finish in one class period.</p>	<p>Students were graded for the completion of the project and the accuracy of their answers.</p>
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<p>G. Controversial Issues – students are assigned to a group and asked to investigate a controversial issue</p>		<p>This assignment differs from the typical student presentation, as students are asked to do it “on the fly.” They are not given a great deal of time to prepare their presentation (as the information is not fundamental for completing the objectives) but must put together a presentation that covers the topic and links it to the unit.</p>	<p>Students generally get one class period to work with their groups to prepare the presentation, and each group will present the following class period.</p>	<p>Students are graded on how well they can cover the topic in a short preparation time, and how fluid the presentation is.</p>
<p>H. Unit Test</p>		<p>Covers all objectives for the unit.</p>	<p>One class period.</p>	<p>Students are graded on the correctness of their answers.</p>

All of these activities as a collective support the acquisition of the skills of scientific inquiry. Scientific inquiry involves engaging students in projects where they can discover material on their own, but feel that they have enough background knowledge to take chances and explore. Regardless of the area of expertise, or the type of intelligence, there are projects within this unit that expose students to an eclectic combination of learning methods. The activities are not listed as sequenced. Students would not receive three to four lecture classes. Instead these would be interspersed with labs and other activities as I see fit. Students are provided with a day-to-day calendar of activities (a syllabus if you will) at the start of each unit.

Technology is an essential and fundamental tool in my classroom. Many of the labs that students will run utilize probeware and computer interface technology to collect data. Students use the internet to gather data, and learn to become shrewd observers of the vast amounts of knowledge. They have designed webpages, and work with database and graphing programs. I believe that technology is fundamental in the development of a Renaissance student in today's world. In fact, I find the state of technology education so important that I published an article about it in the *Howard County Times* ("County schools could learn a few things about tech" in the "Letters" section).

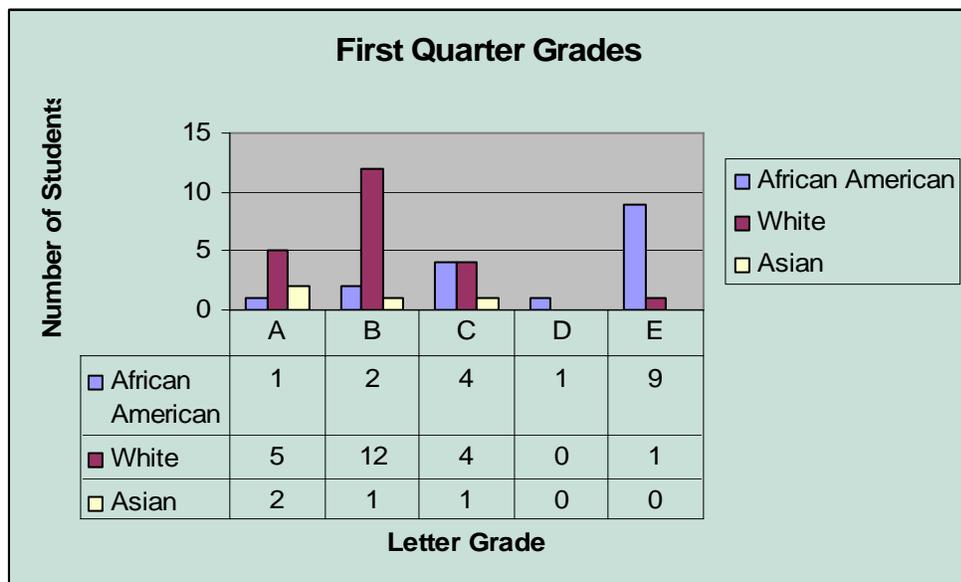
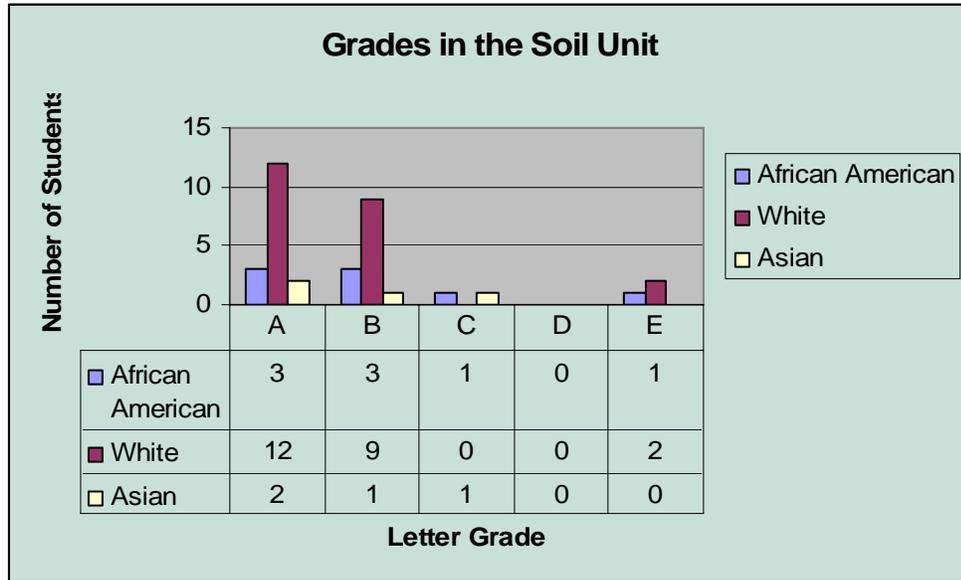
Because this description of the unit is *ex post facto*, it is representative of what I hope to do next year. I did each of the assignments listed above with the exception of two of the labs. These were developed after completing the unit and noticing that something was missing. The flow of this unit was positive, but I would like to provide more laboratory experience. It is also difficult to reflect on the feedback provided to students for their work. Students completed this unit in November and the year has since ended. I often provide a great deal of written feedback on the position journals, raise questions in the lab assignments, and grade the remaining assignments either by a predetermined rubric that simply requires providing numerical feedback, or for tests, using a key. The activities taught in this unit are reflective of how the year runs in AP Environmental Science. Students are met with multiple challenges that require them to call on a variety of learning styles.

Analysis of Learning Results:

It is extremely difficult to reflect on this data as I am so far removed from teaching this unit and no longer have access to the materials that were returned to the students. I will provide grades, however, that demonstrate student progress quantitatively. This is just a sample of the whole class.

ID Number	Soil Lab	Lab Total	Wyoming Reading	GMO	Webquest	Vitamin/Mineral Case	Study/Presentation	Project Total	October Journal	Position Journal Total	Soil/Land Use Test	Test Total	Points Earned	% Grade	Letter Grade
	34	7	0	0	53	10	30	19	50	10	100	40	75		
990762	32	6	10	10	53	9	27	22	25	5	81	32	66	87	B
983568	29	6	10	10	53	10	27	22	41	8.2	90	36	72	95	A
983570	29	6	0	0	53	10	23	17	47	9.4	90	36	68	91	A
983572	31	6	0	0	38	0	22	12	23	4.6	108	43	66	88	B
991707	34	7	0	6	53	0	22	16	45	9	92	37	69	91	A
991771	34	7	10	7	53	10	23	21	41	8.2	94	38	73	97	A
983580	34	7	10	10	53	10	abs	17	46	9.2	93	37	70	93	A
619420	31	6	0	0	53	0	20	15	27	5.4	71	28	55	72	C
604661	31	6	0	0	53	10	30	19	39	7.8	95	38	71	94	A

The data represented here shows how students performed on one lab, several classwork projects, a position journal, and the test. The grades range, but the largest group falls in the A and B category. Students were given the opportunity to complete extra credit in this unit, and many did. Of the 34 students, 10 were African American, 4 were Asian, and 20 were white. It is important to note again that this is an AP course. The graph below shows the breakdown of grades for students for this unit only as compared to the breakdown of grades of the end of the quarter in which this unit was taught. This provides a baseline for which to compare the how well students did on one singular unit as compared to the quarter.



Students who succeeded in this unit did so because they submitted all assignments in a timely manner and took care to ensure that those assignments met the standards of

quality expected in an AP class. Often students who do not do well in a class with me have absence or lack of preparation to blame. Content is generally not the issue, nor is learning style.

Reflection on Teaching and Learning:

Reflection on my instruction and student learning: When I plan, I do not consciously think of teaching strategies. After experience, you learn what works in a classroom, and you neglect to put a name to it. If I had to identify strategies that produce success in the classroom, they might be a variety of teaching methods that address the principles of brain-based learning and multiple intelligences, and fostering an inquiry based environment. Students need to and enjoy learning how to be in control of their own educational experience. Both of these strategies allow me to facilitate the process but put the onus of learning on the student.

Reflection on improving my practice: I am constantly trying to improve my practice. This was the first year that I taught AP environmental science. That I partly why I wanted to reflect on it for this work sample – it allows me the opportunity to look back on my teaching experience in a structured fashion. My lack of individual experience with teaching environmental science contributed to roadblocks in classroom learning. Additionally, my unfamiliarity with the materials of environmental research made me hesitant to do a variety of labs. After a year of experience in this subject area, and an upcoming College Board workshop, I believe I will be well-equipped to handle the course for next year.

Reflection on my knowledge and skills as a science teacher: I believe that I am a good science teacher, and I temper that with as much modesty as I can. We all have to believe that we are good at what we do in order to do it well. I learn from each experience in the classroom and make modifications. I feel that my students achieve a level of academic success and growth partly due to their experience in my science classroom. I really enjoy my job and my students, and I believe the feeling is mutual.

Reflection on possibilities for Professional Development: I believe that professional development opportunities are fundamental for the growth of a teacher. Unfortunately, few meaningful experiences are offered at the county level. I have participated in many professional development opportunities through colleges and universities or government agencies that have allowed me to grow and change as a teacher. They have introduced me to new technologies and new ways of thinking about the classroom. If we want teachers to be professional, then we must afford them the time and opportunity to enhance their professional knowledge, experience and contacts.

Linkage to Scientific and Learning Communities:

Our school currently enjoys an esteemed reputation county-wide for its science department. The regimen laid out here for environmental science is just one example of the multiple ways of organizing a unit with a class within a larger science program. I believe that my goals fit well with those of my fellow teachers, and with county and state

demands. At the same time, I have taken great care to make the program my own – not a scripted learning experience.

Unfortunately, learning communities among teachers only occur when facilitated by teachers themselves. There are not opportunities for teachers to work collaboratively within the school or the system. This is a great downfall of public education – the solitary confinement of the job. Most teachers never have the time or opportunity to share resources. I do collaborate with my fellow chemistry teacher in the building, but I cannot say that I have any knowledge of what happens in other science classrooms.

My students are constantly engaging in cooperative work. I enjoy watching students work in groups, whether they are pairs, small groups, or a whole class discussion. Students must learn how to work with each other. At the same time, students who wish to work along may be afforded the opportunity if the project is appropriate. I find that when people can “bounce” ideas around, they gain much more from an experience, and often leave it with a fresh viewpoint.

My students made contacts with several people outside the classroom over the course of the year, but no one specifically with this unit. We worked with the Department of Energy on hybrid vehicles, and with the Chesapeake Bay Foundation on the Chesapeake Bay Watershed and water health testing. I am currently working with the Audubon Society on a land renovation project and with Habitat for Humanity on having students draw landscapes for home projects that are environmentally friendly.

Appendix E: Interview Questionnaire

Professional Experience:

What level do you teach? ___ Middle School ___ High School

What is your area of certification? (if you have more than one, please list all)

How many years have you been teaching? _____

Perceptions of Professionalism:

Could you describe characteristics of a *professional*? What are these characteristics?

Do you consider yourself a professional? What are the characteristic of teachers that classify them as professionals?

Perceptions of Professional Development:

Do you consider your district's science professional development opportunities beneficial? In what ways? Could you describe your district's approach to professional development?

What could be done to improve professional development at the district level?

Do you believe that district professional development encourages teacher professionalism? Why or why not?

Have you ever participated in a professional development outside of the district, other than LSTPD? Could you describe it and share how it compares to experiences you have had in county sponsored events?

To what extent do science teachers view professional development opportunities as enhancing their professional experience and expertise? Does it vary over grade level and subject areas?

What is quality professional development in science and how does that professional development meet the needs of these teachers?

LSTPD and Professional Development

What are your goals for your participation in LSTPD?

How do you believe this program will be different from those in your district?

What are the teachers' views of the Laboratory Science Teacher Professional Development program?

How does district-mandated professional development compare to the Laboratory Science Teacher Professional Development experience?

How does the science teachers' view of classroom practice change before and after exposure to the Laboratory Science Teacher Professional Development program?

Do teachers anticipate changing their classroom habits, their ideas about teaching science, or some combination of these?

How do their views of teaching as a profession and learning as a process change due to Laboratory Science Teacher Professional Development?

Appendix F: Follow-up Email Correspondence with Participants

Dear friends,

I hope this email finds each of you doing well. It is nearly May, and as you “wind-down” your school year, I would like to ask you for your help, again, with my University of Maryland Research. I mentioned over the summer that I would be in contact with you via email to discuss the role that LSTPD has played in your professional growth and classroom practice. Now that you have taught the large majority of your curriculum, I hope that you will be able to address my questions.

The section in italics below is taken directly from my dissertation proposal, and the answers to these questions were covered during our interviews in the summer. If there is anything you would like to add to enrich my data, it would be appreciated. I wanted to include this to “refresh” you on focus of our many conversations were last summer.

This study addressed the central research questions: “How does an intensive, content research-based professional development program affect science teachers’ learning? How does this, in turn, affect their classroom practice?” There are a number of sub-questions that arise from these central questions, in the context of the Laboratory Science Teacher Professional Development (LSTPD) Program.

- 1) *What is the impact of LSTPD on professional growth, as measured by the participant, in terms of their learning and pedagogical content knowledge?*
- 2) *To what extent do science teachers view professional development opportunities as enhancing their professional experience and expertise? Does it vary over grade level and subject areas?*
 - a. *What is quality professional development in science and how does that professional development meet the needs of these teachers?*
 - b. *What are the teachers’ views of the Laboratory Science Teacher Professional Development program?*
 - c. *How does district-mandated professional development compare to the Laboratory Science Teacher Professional Development experience?*
- 3) *How does the science teachers’ view of classroom practice change before and after exposure to the Laboratory Science Teacher Professional Development program?*
 - a. *Do teachers anticipate changing their classroom habits, their ideas about teaching science, or some combination of these?*
 - b. *How do their views of teaching as a profession and learning as a process change due to Laboratory Science Teacher Professional Development?*

If you could, between now and the end of June, read the following and send me your response, it would be greatly appreciated. In thinking about my research questions, please consider and discuss these:

- 1) Do you make reference to your research experience in your teaching? How?
- 2) Do you convey the science content of your experience to your students? How?
- 3) Do you teach about how science is done with reference to the work you did in your research experience? How?
- 4) Do you discuss the roles of scientists in the construction of knowledge in reference to this research experience? How?

Appendix G: The Author's Professional Development Plan from 2006

A PERSONAL PROFESSIONAL DEVELOPMENT PLAN

Laboratory Science Teacher Professional Development (LSTPD) Program
U. S. Department of Energy
Office of Science: Workforce Development for Teachers and Scientists

LSTPD Participant: **Melissa Lynn Kiehl**

Name of School: **Oakland Mills High School, Columbia, MD**

Host Laboratory: **Lawrence Berkeley Laboratory**

Research Assignment

Summer #2: Environmental Energy Technologies **Mentor:** Nancy Brown

Nancy Brown recently started work on a study independent of other groups at the lab, and related to transport properties of fluids. I have been assigned to work with this body of research, specifically reviewing transport properties that are important in combustion modeling of simple fuels like H₂ and natural gas. The goal is to gain an understanding of transport at the molecular scale, and use viscosity data to extract potential constants for the intermolecular potential for binary systems.

Transport properties are phenomena ubiquitous with human life. Fluid molecules (gases or liquids) are in constant motion, and has such exhibit any and all of three transport properties: conduction/convection, diffusion, and viscosity. Each transport property requires the presence of a gradient. Conduction is the transfer of heat (convection, more specifically is the transfer of heat through a liquid or gas). Diffusion is the transfer of mass. Viscosity of the transfer of momentum. They are neither totally independent, nor mutually exclusive.

The ultimate milestones of my contribution to the understanding of transport properties are: a) to report on measurements of viscosity, diffusion, and thermal conductivity; b) determine potential parameters for some binary pairs that are important in combustion (note some are already reviewed and tabulated and others will be taken from the literature); c) tabulate transport properties that are accumulated from literature review.

Background/Teaching Context:

Oakland Mills High School is located in Howard County, Maryland. Howard County Public Schools are highly regarded as being one of the top systems in the state. Additionally, there is tremendous wealth in the county, but it is highly concentrated in certain districts. Oakland Mills represents a more diverse environment, both racially and economically. The approximate population breakdown is 48% African American, 43% White non-Hispanic, 4% Hispanic, and 5% Asian and Middle Eastern. Additionally,

Oakland Mills is home to many families of mixed cultures, meaning that students have parents from different racial or ethnic backgrounds. Oakland Mills is located in Columbia, MD, an area widely known by civil engineers and cultural anthropologists for James Rouse. Rouse, who designed Columbia as a planned community, envisioned an area where people of all socioeconomic backgrounds could live in the same communities. For this reason, a percentage of housing in all hamlets of Columbia is reserved for those receiving government subsidies. Oakland Mills is home to the largest number of students living in government subsidized housing and receiving federal aid. FARMS (free and reduced meals) data indicates that approximately 17% of students receive aid of this kind. While this number is strikingly low when compared to more urban environments, it is unusual given the culture and wealth of Howard County. For this reason, the school is unique.

Teaching in this environment is a unique and rewarding experience. As a graduate of the Howard County Public School System, I am constantly impressed with the drive for academic success. What I never understood as a student in a more homogenous school was the beauty of diversity within the county. Students at Oakland Mills cannot be neatly placed into cliques in the traditional sense. There is a community in the school that is echoed with students, parents, and teachers. Most students attended elementary and middle school together before entering Oakland Mills, and have come to know diversity in a way that cannot be appropriately described. They identify and understand differences, but never shun or disrespect as a result. This is not to suggest that this is a Utopian environment. Oakland Mills is fraught with problems, including a large struggling African-American male population, and disconcerting drop-out and attendance rates. The dedication demonstrated by those that work for and in that community helps to maintain balance.

As a teacher of science in Oakland Mills, I am constantly challenged to find what makes my students tick. In three years of teaching, I have amassed a protocol that works for me, but that is constantly changing. I consider my classroom a friendly but firm environment. I know each student personally – what they like to do in their free time, what they want to be, the subjects they enjoy and those they dislike, and often personal information that they feel comfortable sharing. At the same time, students understand that there are rules and guidelines. Because I teacher older students (juniors and seniors), the time to coddle has passed. My goal is to prepare them for what is to come – college, a career, the military, etc. I have a mantra, “If you didn’t get the grade you wanted, I didn’t get the work I wanted.” In reality, students are learning an important lesson – that life is only partly about what you know. The rest is how you play the game – can you complete something in a timely manner, are you dependable, can you seek help when you need it, etc.

I have taught three distinct levels of learners. The “lowest” tier would be those enrolled in Introduction to Chemistry and Physics (ICP). The next would be the Chemistry students. The final group is AP Environmental Science. While I modify some instruction for the students in my ICP class, I hold them to the same high expectations as I would my other classes. We often place a larger emphasis on the bigger picture of

scientific study, and then add the details as evidence. For example, we discuss the plethora of uses of organic compounds, and then the chemistry behind them. In chemistry, context is equally important, but students are asked, in accordance with state and local standards, to learn very specific details behind chemistry. I feel that many tidbits of information throughout the twelve units are unnecessary at the high-school level. Given that many students will not remember the details after my class, I try to teach them in such a way that promotes other skills, like mental organization, analogy, and graphical representation. Stimulating other arenas of learning is equally important (if not more so) than ensuring that students understand each shred of material.

The focus of the AP Environmental class is slightly different (and a unit from this class will be discussed in this work sample). Because these students are taking a course for which they may be awarded college credit, it is extremely important to me that I prepare them for college work. As someone with a bachelor's degree, master's degree, and working on a doctorate degree, I feel that I can be of service in preparing these students for the rigors of college. I work with these students on enhancing the following skills: critical reading and writing, conducting scholarly research, defending an argument or thesis, completing inquiry based activities on an independent level, and becoming technology savvy. Students are often rudely awakened by the expectations of college professors in the arenas of research and writing. While they are reluctant at first to embrace these activities in science, they quickly learn that these are fundamental in all areas of academia.

Goals and Objectives:

- Long Term Goals
 - One of my current long term goal is the successful completion of my doctorate program at the University of Maryland College Park. My focus of study is professional development for science teachers, specifically the LSTPD program. This summer will be the initial research phase which will continue into early fall. The rest of the academic year will be spent revising and writing the dissertation. The proposed defense date is the end of the academic year, 2006-2007.
 - Upon completion of my degree, I hope to move into a position in our district known as the Gifted and Talented Resource Teacher. There is one teacher assigned to each school, and this person facilitates year-long, intensive research projects with students that are either independent in nature, or guided by a mentor in the local community. All projects culminate in a scholarly paper and a product or artifact.
- Near Term Objectives
 - I would very much like to attend the NARST convention to see how leading science education researchers are creating new knowledge in the field, and the techniques they use to present that knowledge.
 - I would like to edit the curriculum that I used last year to make sure that I am meeting the needs of students and keeping current on best practice. I would like to introduce some new, fresh lessons, and re-order my AP Environmental units.

- I would like to attend the local area NSTA convention in order to network with area teachers and science education providers.

LEADERSHIP PLAN

Steps/Strategies to Achieve Goals and Objectives(The Plan-Who, What, Where,& When)

1. Continue to follow a strict timeline for completing research related to the University of Maryland. Devote pre-determined blocks of time to intensive revision and writing.
2. Begin reading more about gifted learning, since coursework in this area will not fit into my professional timeline this year. Set aside funds to take a gifted learner course as soon as possible.
3. Consider putting together a poster to present at the NARST convention, as recommended by my advisor.

Timeline Description (Activities, Conferences, Reports, Presentations, etc.)

- Year #2
 - July/August – complete all interviews and observations related to University of Maryland Research; begin revising dissertation proposal
 - September/October – continue revisions; maintain contact with participants through the first two months of school to see how they are implementing their work from the lab into their classrooms
 - November/December – complete all revisions of the paper; submit first draft to advisor for January review; attend local NSTA conference
 - January – March – continued revisions of paper; plan poster presentation if desired; set date for defense; put in transfer paperwork for G/T position
 - April – dissertation defense; learn results of transfer request; attend NARST conference
 - May – graduation from University of Maryland
 - June – end of school year
- Year #3
 - July – attend LSTPD for third year; plan funds for a laptop purchase to take to new school
 - August – enroll in Gifted Learner class; transition into role as gifted educator
 - Date undetermined – attend large national conference on either science or gifted learning

Evidence for Achieving Goals and Objectives/Evaluation for each Step or Strategy

- The dissertation and ultimate graduation from University of Maryland will serve as evidence that this goal was achieved.
- The successful transition to a role as a Gifted and Talented educator would serve as evidence that this goal was achieved.

- Utilization and implementation of new methods as a result of attending NARST, as well as the potential to share the LSTPD research with a larger science education research audience would be evidence of this endeavor.

Reflection and Documentation on How Plan is Working and how it might have been improved or implemented differently.

- I have made great progress in meeting the goals I set forth in my first year at the lab. I had hoped to get a successful AP program off the ground, and feel I have done that. I am constantly refining the course, but have the materials, and knowledge to prepare students for this challenging exam.
- I had also put forth the goal of progressing in my doctorate program. Since that PDP, I completed my coursework, my comprehensive exams, defended my proposal, and successfully advanced to candidacy.
- I had planned to attend NSTA and AAAS. While I was successful in attending NSTA, I would still like to attend AAAS, as well as many other professional conferences.

Budget/Proposal

- Mini Grant (Equipment, Materials, Supplies, etc.)
 - Please see attached spreadsheet
- Travel (Professional Meetings, Conferences, etc.)
 - National Association for Research in Science Teaching (NARST) – Annual conference, April 14 through the 17th, 2007, New Orleans, LA

Cost Item	My Estimate
Airline	\$250
Lodging – 3 nights	\$500
Registration	\$80*
Per Diem (@\$59/day, and \$44.25 for travel days)	\$206.50
Total	\$1036.50

*Registration fee for Graduate Students who are NARST members, confirmed by email. Registration opens in February.

- National Science Teaching Association (NSTA) – local conference, November 2 through the 3rd, 2006, Baltimore, MD

Cost Item	My Estimate
Registration	\$120**
Per Diem (75% of \$59 for two days)	\$29.50
Total	\$149.50

**Registration fee confirmed by NSTA. Registration is open, and early-bird ends in September.

Total Requested funds: \$1186.00

Budget Justification:

I am in a different stage in my career than other participants. My main goal right now is to move through the dissertation process successfully and put forth a piece of research that adds to the body of knowledge on professional development for science teachers. I hope to use this research experience at the University of Maryland to propel me into new and different opportunities in the field. I think that the texts I have requested in the mini-grants will both aid in my research, and the research of my students, as well as prepare me for the potential role as a gifted and talented educator. I utilize a great deal of technology in my teaching, and rather than borrow equipment from my family and friends, I would like to use the grant to purchase many of the things that I currently use, but that do not belong to me. That way, no matter where I work, I can take these pieces of equipment with me, including the computer peripherals and the fax machine.

I have been encouraged by my University advisor to both attend and present at the NARST convention this year. Normally, the cost of this convention would be a hardship, but the conference funds would allow me to be a part of this year's national conference. Additionally, I am fortunate enough to live in the city where the Area Conference for NSTA is scheduled. I think it would be an outstanding opportunity to attend this conference, seeing as the only expenses I would incur are the registration, lunch, and parking.

Appendix H: IRB Proposal and Consent Form

Abstract

Professional development generally refers to the collection of activities that enhance a teacher's professional career growth. Collaborative, reform models of professional development tend to focus on the development of communities where teachers engage in some kind of authentic activity (Butler et. al., 2004). The National Research Council recommends that science teachers actively engage in investigating phenomena, addressing issues in science, building their own understandings, reflecting on the process of inquiry, and working collaboratively during professional development (NRC, 1996). Given the complexity of our present reform initiatives, our current model of professional growth, focused largely on expanding a repertoire of skills, is not adequate (Little, 1993). The Laboratory Science Teacher Professional Development Program (LSTPD) is run through the United States Department of Energy (DOE). I will be working with teachers in all phases of the program – first year through third (and final) year participants. The main research questions to be examined are, “How does an intensive, content-based professional development program impact science teachers’ learning? How does this affect change in their classroom practice?” I will attempt to gather information through survey data, program evaluation, and intensive interviews – all components of case study analysis. The link between science teacher learning and professional development opportunities is of importance if we hope to achieve the goals set forth by the NRC.

Subject Selection

Subjects will be secondary science teachers participating in the Laboratory Science Teacher Professional Development Program in Berkeley, California. This is a small group of individuals, from which I will ask for voluntary participation in the study. Subject will be selected based on the number of years they have participated in the program – ranging from one to three years. Subgroups will be organized based on this information. My goal is to work with six participants – two from each level of participation in the program. Participants agree to three summers of participation, meaning that there will be three stages of participation. In the summer of 2006 when I conduct this research, there will be teachers completing their third year, those in their second, and new participants. I feel that working with two participants from each level will suit my research purpose and allow for a reasonable amount of data.

Procedure

Quantitative data collection will take the form of a survey generated by the Department of Energy. The survey is completed before arrival at the lab, generally in March and April. The goal for me in using this survey is to gain a baseline understanding of the teaching in which the participants engage, how often they participate in professional development, what types of assessment they currently use in their classroom,

and what they hope to gain from the program. From this data, I will generate a series of interview questions for the six participants.

Qualitative data collection will take the form of these interview questions. I will meet with participants each week for interviews. I will meet with all groups separately, meaning that I will meet with those on their third year, second year, and first year on an individual basis. This is necessitated by the fact that participants may choose to work at the lab for as little as 2 weeks if they are in their third year, or as many as 8 weeks. All first-year participants are required to work in the lab for 6-8 weeks. These interviews will be audio-recorded, and transcribed. Additionally, I will take notes during the interview and use those notes to guide future interviews. All of this information will be stored in locked storage bins in my place of residence. The meetings will last one hour. At most, participants will be asked to engage in 8 one-hour visits.

I will follow up with participants during the first two months of the school year (September and October) using electronic surveys. The goal of these surveys is to assess whether the teachers have changed their practice, or their views on professionalism and professional development, as a result of their participation in the program.

Risks and Benefits

There are no risks to the subjects. Potential benefits include improved professional development opportunities at the county level, and networking opportunities for the community of teachers who volunteer to participate.

Confidentiality

Human subjects will be protected throughout the study by providing pseudonyms. Specific information about the districts and schools that employ participants will also be changed. Data will be stored in the researcher's home rather than the workplace, a Howard County Public School. Data will be collected from April 2006 through October 2006 at the Berkeley Lab in Berkeley, California. The only people with initial access to the research data will be the researcher and her advisor. Eventually, findings will be made available to the Department of Energy and the Ernest O. Lawrence Berkeley Lab. Upon completion of data collection, all taped interviews and surveys will be destroyed in a method that is environmentally appropriate.

Information and Consent Forms

Participants are entitled to full disclosure in this research project. They will be fully informed as to the research goals and objectives, and will be provided with the final data analysis for approval. The informed consent letter is attached.

Conflict of Interest

There is no conflict of interest for the participants because their identity will be protected and the research presents no threat to the Department of Energy or the University of Maryland College Park.

HIPAA Compliance

This is not applicable.

Research Outside of the United States

This is not applicable.

Research Involving Prisoners

This is not applicable.

CONSENT FORM

Project Title	<i>Connections between Teacher Learning and Professional Development: An Examination of the Laboratory Science Teacher Professional Development Program</i>
Why is this research being done?	<i>This is a research project being conducted by Melissa Kiehl at the University of Maryland, College Park. We are inviting you to participate in this research project because you are a participant in the Laboratory Science Teacher Professional Development Program. You are a possible research candidate because of your interest and selection in this program. The purpose of this research project is to investigate the LSTPD program and learn how it shapes your view of professional development. Additionally, I would like to learn how it impacts you as a teacher once you return to your classroom.</i>
What will I be asked to do?	<i>I will analyze all of the Department of Energy surveys completed online at the start of your LSTPD participation for the LSTPD participants in their second and third years of participation. The procedures involve an individual interview upon arrival to the lab, and approximately two weeks into the program. Additionally, there will be one focus group interview where all participants will be in attendance at the end of the program. The interviews, which will be audiotaped, will last approximately one hour. I would like to observe you in your research setting for two fifteen minute intervals – one at the start of the program and one at the end. You will be asked a variety of questions related to your feelings about professional development. These questions will be attached to information you will receive prior to beginning the LSTPD program. I will continue to follow up with you through October, 2006. I will do this through electronic correspondence- approximately twice, once in September, and once in October. I ask that the</i>

	<i>correspondence take the form of an email journal, where you reflect on professional development and implementation of the goals of the LSTPD program. If more conversation is needed, we will discuss this individually. My goal is to see how you are continuing to reshape your professional growth as a result of your participation in the LSTPD program. All audiotapes, notes, and observation data will be stored in locked bins in my place of residence. After the research period has ended the tapes will remain at my place of residence indefinitely.</i>
What about confidentiality?	<i>Your personal information will be kept confidential. To help protect your confidentiality, all data will be stored in locked storage bins and in password-protected computer files. Surveys will be coded with pseudonyms to maintain confidentiality. Any information with your name, such as email correspondence will not be directly included in the final data analysis. If we write a report or article about this research project, your identity will be protected to the maximum extent possible. Your information may be shared with representatives of the University of Maryland, College Park or governmental authorities if you or someone else is in danger or if we are required to do so by law. In accordance with legal requirements and/or professional standards, we will disclose to the appropriate individuals and/or authorities information that comes to our attention concerning child abuse or neglect or potential harm to you or others.</i>
What are the risks of this research?	<i>There are no known risks associated with participating in this research project.</i>
What are the benefits of this research?	<i>This research is not designed to help you personally, but the results may help the investigator learn more about professional development for science teachers. In the future, other people might benefit from this study through improved understanding of how teachers learn, and what type of professional growth they need to be successful professionals.</i>
Do I have to be in this research? May I stop participating at any time?	<i>Your participation in this research is completely voluntary. You may choose not to take part at all. If you decide to participate in this research, you may stop participating at any time. If you decide not to participate in this study or if you stop participating at any time, you will not be penalized or lose any benefits to which you otherwise qualify.</i>
What if I have questions?	<i>This research is being conducted by Dr. J. Randy McGinnis at the University of Maryland, College Park. If you have any questions about the research study itself, please contact Melissa Kiehl at: 410-530-0013 or 17 Tanglewood Road, Catonsville, MD 21228; lissacook@comcast.net. If you have questions about your rights as a research subject or wish to report a research-related injury, please contact: Institutional Review Board Office, University of Maryland, College Park, Maryland, 20742; (e-mail) irb@deans.umd.edu; (telephone) 301-405-0678 This research has been reviewed according to the University of</i>

	<i>Maryland, College Park IRB procedures for research involving human subjects.</i>	
Statement of Age of Subject and Consent [Please note: Parental consent always needed for minors.]	<i>Your signature indicates that: you are at least 18 years of age;; the research has been explained to you; your questions have been fully answered; and you freely and voluntarily choose to participate in this research project.</i>	
Signature and Date <i>[Please add name, signature, and date lines to the final page of your consent form]</i>	NAME OF SUBJECT	
	SIGNATURE OF SUBJECT	
	DATE	

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