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Legitimate Peripheral Participation of Secondary Educators in Scientific Research Experiences: Implications for Teachers' Understanding of the Nature of Science and Classroom Teaching

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To the Graduate Council:

I am submitting herewith a dissertation written by Matthew Phillip Perkins entitled "Legitimate Peripheral Participation of Secondary Educators in Scientific Research Experiences: Implications for Teachers' Understanding of the Nature of Science and Classroom Teaching." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Education.

Rita A. Hagevik, Major Professor

We have read this dissertation and recommend its acceptance:

Gary J. Skolits, Stephanie O. Robinson, Michael Bentley

Accepted for the Council:

Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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A Dissertation Presented for
the Doctorate of Philosophy
The University of Tennessee, Knoxville

Matthew Phillip Perkins
May 2010

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ABSTRACT

Both of the national reform efforts (AAAS, 1993; NRC, 1996) encouraged teachers to engage in professional development that included authentic scientific research experiences. The Department of Energy developed a program to match teachers with mentor scientists at national laboratories for three consecutive summers. Teachers produced and presented a poster summarizing their research at the conclusion of each summer.

The purpose of this qualitative multiple case study was to better understand how scientific research experiences impacted teachers. Six dimensions were examined: trajectory of participation, content knowledge development, mentor relationships, beliefs about the nature of science, teacher confidence, and classroom practice. These six dimensions were integrated into three research questions which guided the research: the teachers' ability to increase their level of participation from the first to the last summer of research, the teachers' changes in their understanding of the nature of science (NOS), and any changes in the teachers' classroom teaching because of their involvement in the program.

In-depth interviews were triangulated with teachers' posters to provide insights into teachers' legitimate peripheral participation in the research laboratory. The VNOS-C (Lederman et al., 2002) was administered pre/post to the teachers. Evidence of more informed, developing, and more naive understandings of each of the tenets of NOS was collected and compared to identify changes in teachers' beliefs. Interviews and follow-up correspondence informed the study of changes in classroom teaching.

The teachers became very familiar with their mentors' research, increased their subject content knowledge, and contributed to their mentor's work. Mentors utilized teachers' expertise as communicators when presenting research and hosting other student groups. The teachers' understanding of the NOS did not change as a result of their immersion in the culture of the laboratory. The lens through which the teachers viewed science influenced how they perceived and interpreted their research experiences. Teachers who held positivist views reinforced them, while the lone teacher who held post-positivist views reinforced their positions. The teachers developed confidence in their ability to facilitate classroom inquiry, increased the number of inquiry-based in their curriculum, introduced advanced placement and scientific research courses, and rejuvenated their enthusiasm for teaching.

KEYWORDS

teacher; scientist; laboratory; scientific research experiences; scientific work experiences; legitimate peripheral participation; community of practice; trajectory of participation; learning; content knowledge; nature of science; classroom; pedagogy; teacher confidence; inquiry; science teacher education; professional development; inscription

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CHAPTER I

INTRODUCTION

Traditional university science education has often been segregated into narrow, content specific disciplines (physics, chemistry, biology, geology). Such specialization of courses is deemed necessary in order for an aspiring student to become a member of the scientific community. The few opportunities available for science teachers to participate in the scientific laboratory as a university student are limited to verification level experiments that consistently produce expected outcomes. For example, Roth, McGinn, and Bowen’s (1998) analysis of undergraduate biology courses revealed that introductory courses often did not provide adequate opportunities for teachers to learn how to analyze scientific data. In their study, the inability of practicing science teachers to transform scientific data from one form (list, table) to another (graph, equation, diagram) was considered to be a direct consequence of the teachers’ limited opportunities to experience authentic scientific research. The teachers failed to approach or to analyze data in the same way as a sample group of practicing scientists. Roth, McGinn, and Bowen concluded that many science teachers simply did not have extensive experience participating in scientific research and as a result were less comfortable creating opportunities for investigation in their own classrooms.

The National Science Education Standards (NSES) (National Research Council, 1996) address the need for teachers to have professional development opportunities in which they participated in scientific research. Professional Development Standard A recognizes that teachers learn “essential science content through the perspectives and methods of inquiry” (p. 59). Mastery of science content is defined by the same standard as a teacher being “familiar enough with a science discipline to take part in research activities within that discipline” (p. 60). Inquiry is so significant that Standard A declares “[professional development] 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” (p. 59).

Professional Development Standard C connects participation in inquiry to improved teaching. Standard C requires professional development activities to “provide opportunities to learn and use the skills of research to generate new knowledge about science and the teaching and learning of science” (p. 68). Becoming the student again provides teachers with fresh opportunities to gain insights into the misconceptions and other difficulties secondary students encounter when learning science. Not only do the teachers face their own misconceptions, they develop a deeper connection with the content, inspiring the design of new lessons, activities, and approaches to teaching a particular concept. Engagement in research activities inspires teachers to translate their new knowledge into better science teaching.

Traditionally, teachers are not asked to become scientists before becoming science teachers. With the exception of those professionals who left careers in the sciences for a second career in education, science teachers rarely have had extensive experience in scientific laboratories (National Research Council [NRC], 1996). But science teachers must achieve a level of confidence and comfort with authentic scientific inquiry in order to move beyond a subject-centered classroom, limited to the rote memorization of science facts and performance of verification laboratories with predetermined outcomes. Authentic laboratory research experiences for teachers promise to satisfy NSES Standards A and C by providing opportunities for teachers to experience inquiry first-hand and to become familiar with the activities scientists engage in to develop new knowledge about science.

Statement of the Problem

The theory of legitimate peripheral participation (LPP), crafted by Lave and Wenger (1991) is based on their observations of a variety of apprenticeships and serves as a meaningful framework for examining the science teachers' mentorship experiences. LPP defines learning in terms of increased participation within an established community of practice. While the intent of laboratory professional development is not the progression of teachers to becoming full-time laboratory scientists, LPP provides a framework for measuring the extent to which the teachers are able to become more informed through participation in the processes of science. Increases in a teacher's participation in the mentor's research suggests that the teacher learned as a result of their research experience.

The teachers examined in this study were qualified to assist in the research activities of a professional laboratory by virtue of their undergraduate degrees in a specific field of science and years of participation in the classroom as teachers of science. Some of the teachers participated in limited scientific research during their undergraduate or graduate studies, and a couple had work experience in a scientific field prior to becoming a teacher.

The science teacher was integrated into a new environment, the scientific laboratory, as a high-potential novice scientist. The research design was the invention of the mentor scientist, who maintained ultimate control over the direction of the inquiry. No one expected the teachers to advance to careers in research science, a process that demanded years of apprenticeship and coursework for scientists to accomplish. The question was to what degree could a teacher increase their participation? Were teachers able to improve their understanding of the nature of science as a result of participation? How did the teachers' classrooms change because of their experiences?

The focus of this study was to determine the impact of long term scientific research experiences on inservice science teachers. This study provided evidence of three general kinds of transformations. The first transformation involved the teachers' ability to increase their participation in their mentor's research projects. The second transformation involved changes in teachers' understanding of the nature of science and scientific research. The third transformation was the evolution of the teachers' classrooms. Interviews, surveys, and posters served as evidence.

Research Design

Background

Oak Ridge National Laboratory (ORNL) began as a Manhattan Project facility during World War II, charged with developing technologies necessary for producing and separating fissionable uranium and plutonium for the atomic bomb. After the war ended the laboratory reinvented itself as a diverse research community investigating an array of topics. Today the laboratory is one of ten national laboratories overseen by the Office of Science of the Department of Energy (U.S. Department of Energy, 2009). Over 4,300 people are permanently employed by the laboratory and 3,000 guest researchers visit annually for periods of two weeks or longer (Stair, 2008). The research conducted at Oak Ridge National Laboratory is organized around six scientific themes: biological science, neutron science, advanced materials, national security, high performance computing, and energy. (Oak Ridge National Laboratory, 2009).

The laboratory has created many opportunities for educators to participate in the practice and translation of scientific discovery. Oak Ridge Associated Universities (ORAU) is a consortium of 99 doctoral-degree granting colleges and universities partnering to create collaborations between industry, academia, and government (Hackler, 2009). The Oak Ridge Institute for Science and Education (ORISE), a part of ORAU, is responsible the Science Education Program, which coordinates research experiences for undergraduate science majors, post doctoral research appointments, preservice and secondary educators, and college and university faculty (Stevenson, 2009).

The Laboratory Science Teacher Professional Development (LSTPD) program opened to science teachers grades 7-12 in the summer of 2004. Though other experiences for teachers preceded LSTPD, this incarnation of professional development was unique for several reasons. Participating teachers committed to eight weeks of research each summer for three consecutive years, as opposed to one summer appointments. The role of teachers engaged at Oak Ridge National Laboratory was to shift from being laboratory assistants to becoming active ambassadors of the research being conducted. Each forty hour research week included four hours of professional development in science education during a Friday morning session in the participants' first year of the program. The author of this study was privileged to be a part of the team from a large southeastern university that designed and implemented this professional development. Teachers were required not only to give poster presentations of their research at the conclusion of each summer but to create and share lesson and unit plans to take their experiences back to their classrooms. Professional development funds encouraged the presentation of their work at regional and national conferences.

In 2006 the program changed names to become the Department of Energy Academies Creating Teacher Scientists (DOE-ACTS) (Walbridge, 2006). Little about the structure of the program changed. In 2008 due to a shortage of funds, the program was unable to add new teachers. Teachers who had already started three year appointments in previous years were able to continue. Funding for new teacher cohorts was restored for summer 2009, with eleven teachers assigned to Oak Ridge National Laboratory.

Description of Teachers Participating in Authentic Scientific Research

Four cohorts of teachers thus far have completed three summers of scientific research experiences at Oak Ridge National Laboratory. Each teacher was assigned a mentor scientist and appointed to serve in his or her laboratory work for three consecutive summers. Occasionally teachers opted to switch mentors between summers. The cohorts were differentiated by their first year of research. As many as three cohorts coexisted at the laboratory in a given summer, allowing for limited social interaction between the groups.

Cohort I included four inservice secondary science teachers from east Tennessee who began their research in summer 2004. The next summer Cohort I continued their work as four additional teachers from the region became Cohort II. Additional grant monies and mentors allowed for the expansion of the program in 2006 to include twelve new teachers in Cohort III. Several of the teachers of Cohort III came from outside the region, including Kentucky, Texas, Indiana, and North Carolina. Cohort IV began appointments in 2007 and was composed of five teachers, four from within a 100 mile radius of the laboratory and a fifth from out of state.

Fifteen of the teachers were primarily assigned to teach biology, six taught primarily chemistry courses, three taught physics or physical science, and one was a mathematics and computer science instructor. Six of the teachers had taught for more than 20 years, four had taught for 11-20 years, seven had taught for 6-10 years, and eight were in their first five years of their career when they begun the program. See Table 1.

This study was constructed to investigate three research questions. Six teachers from cohorts III and IV were chosen and a case study design was used to explore and describe their experiences in the program.

Table 1. Demographic breakdown of all LSTPD/DOE ACTS teachers

Category	**Subcategory**	**Cohort I** (2004-2006)	**Cohort II** (2005-2007)	**Cohort III** (2006-2008)	**Cohort IV** (2007-2009)	**Total**
Cohort	Number of Participants	4	4	12	5	25
Gender	Male	3	1	3	3	10
	Female	1	3	9	2	15
Ethnicity	African American	0	0	3	0	3
	Caucasian	4	4	9	5	22
Years Teaching (as of first year)	0-5	2	3	1	2	8
	6-10	0	0	4	3	7
	11-20	1	0	3	0	4
	21+	1	1	4	0	6
Expertise	Biology	3	2	7	3	15
	Chemistry	1	1	3	1	6
	Physics	0	1	2	0	3
	Mathematics	0	0	0	1	1
Grade Taught	Secondary	4	4	10	5	23
	Middle	0	0	2	0	2
Career Experience	Second Career	0	2	4	1	7
	Teaching only	4	2	8	4	18
Location	Tennessee	4	4	5	4	18
	Indiana	0	0	1	0	1
	Louisiana	0	0	1	0	1
	Kentucky	0	0	1	0	1
	Nebraska	0	0	1	0	1
	North Carolina	0	0	1	0	1
	Ohio	0	0	0	1	1
	Texas	0	0	2	0	2
Experience conducting scientific research	Extensive (5+ years)	1	0	1	1	3
	Limited (1-4 years)	1	2	6	1	8
	none	2	2	5	3	14

Research Questions

The following research questions guided this investigation:

1. To what degree were the teachers able to increase their participation, thus becoming more valuable to the sensemaking of data and observations and otherwise able to contribute to their mentor's research agenda?
2. To what degree were the teachers learning about the nature of science through participation in scientific research?
3. How did participation in authentic scientific research impact the teachers' classrooms?

Methods and Procedures

The researcher first became acquainted with the population through the first year educational professional development component. During each cohort's first year, the researcher assisted a veteran science education professor in constructing activities in the nature of science, the use of inscriptions and scientific notebooks, and the learning of students. Survey data pre/post during the professional development course examined the impact and influence of the activities on the teachers.

This study can be best described as a qualitative participant observation multiple case study. Despite the cancellation of Cohort V, the researcher was granted access to the laboratory's visitor center for a three week span in the summer to interview members of Cohort III and IV. Additionally, the researcher was invited to attend the poster session given by the teacher researchers at the conclusion of the summer and to attend several talks given by mentor scientists and their teachers. These opportunities for observation and field notes, along with interviews with the teachers and the program director, participation as a facilitator of the education professional development component, and the collection of artifacts such as laboratory journals, qualify the study as participant observation, as defined by Hatch (2002).

Multiple types of data existed from the first year of each cohort's research. Data collection for Cohorts I and II included laboratory journals and pre and post tests of the teachers' perceptions of the nature of science and scientific methods. Instruments included a Technology survey created for the Salish I project (Fraser, 1993), and a battery of three Likert-scale instruments (Hemler, 1997) to collect pre and post data for the teachers' first year of participation in research. These five instruments focused on the teachers' perceptions of scientific research and their understanding of the nature of science.

In addition to the survey instruments administered to the first two cohorts, the Views of the Nature of Science, Form C (VNOS-C) was administered to Cohorts III and IV in the first session of the classroom professional development during their first summer in the program (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2001).

The VNOS-C was administered to Cohort III and IV participants for a second time in spring 2009 in order to compare the teachers' initial beliefs about the nature of science with those they held after completing three years of immersion in a scientific laboratory.

As described by Lave and Wenger (1991), learning is defined as increasing participation in a community of practice. In-depth interviews were conducted with the teachers during the summer and fall of 2008 with the purpose of realizing the degree to which the teachers had increased their participation in their mentor's research agenda from their first year to their last. Improved subject knowledge was determined though the teachers' descriptions of the research they conducted. Likewise gains in science process skills were determined through careful analysis of the interviews. Thus, the semi-structured interviews were used to measure science learning, in terms of increases in the teachers' ability to participate legitimately in the community of practice (scientists).

While it must be acknowledged that the goal of the research program was not for the teachers to become professional scientists, increased participation in the community of practice is a legitimate measure of the teachers' learning. The National Science Education Standards (NRC, 1996) explain that participation in inquiry-based research is a necessary component of inservice professional development. Melear, Goodlaxson, Warne, & Hickok (2000) found that experience in conducting inquiry-based scientific research better prepared teachers to model inquiry methods in the secondary science classroom. Further research into teacher research experiences by Brown and Melear (2007) revealed that authentic science research experiences for teachers improved content knowledge and increased science process skills.

The semi-structured interview data were coded using the qualitative software program QDA Miner (qualitative data analysis). The VNOS-C pre and post data were coded by conventional means. A typological approach to the data analysis was employed (Hatch, 2002, LeCompte & Preissle, 1993). Three sets of categories were established, one for each of the three primary research questions. A cursory set of subcategories was constructed and modified throughout the initial coding process. These subcategories were based on data from Cohorts I and II and established ideas from the literature on the nature of science and legitimate peripheral participation. Throughout the first reading of the data, codes were added or modified to reflect the available information. Interrater reliability of the interviews and the VNOS-C data was determined by six other researchers. The case studies and cross-case analysis were member-checked by the participants in the study.

Assumptions

The following assumptions underlie this study:

1. The LSTPD/DOE ACTS program was designed to afford teachers the opportunity to increase their level of participation as they become more acquainted with the scientific research laboratory. Level of participation was defined as increasing expertise in the ability to design and pursue new and complimentary experiments and participate in interpretation (sensemaking) of all data.
2. The participating teachers in the study were comfortable sharing about their experiences and were able to speak freely about their relationships with mentor scientists, the program director, and other teachers without fear of repercussion from the laboratory or their school of employment.

3. The participating teachers provided honest answers to the VNOS-C and other instruments as opposed to the answers they felt were ‘correct’ in the eyes of the education community.
4. The posters genuinely reflected the teachers’ participation in the scientists’ laboratory. Teachers generated all parts of their posters under the guidance of their mentor scientist.

Limitations

The following limitations underlie the study:

1. The researcher was not able to directly observe the teachers and/or the mentor scientists as they worked in the professional laboratories. Any direct access to the lab required a security clearance and an approved agenda. Admission to the laboratory was limited to authorized personnel only. A request for permission to observe teachers directly at work was denied by Oak Ridge National Laboratory.
2. The researcher was unable to interview mentoring scientists due to both time constraints and restricted access to the laboratory. The researcher met the mentoring scientists only briefly during public presentations and annual poster sessions.
3. The researcher was limited in his ability to understand the specific details of each research project. Thus the researcher was unable to judge the quality or genius of the research based on any details other than teachers’ self-reports and the sophistication of the poster projects.

4. The researcher was limited in his ability to understand the highly specialized science content being examined in each research project. Thus the researcher was unable to determine the teachers’ increased content knowledge by any other means than the teachers’ increasing ability to participate in scientific research.

Importance

A review of fifteen years of research examining scientific research experiences (SRE’s) for teachers left many questions open for investigation. Little is known about the impact of participation in scientific research on teachers. No studies have followed teachers for an extended period of time to examine the longitudinal impact of participation in research. No existing study has examined the impact of repeated research experiences.

The continuity of research topics afforded these teachers the opportunity to progress from novices to a level of competency never before observed for science educators. While the science teachers were not becoming full-time laboratory scientists, by the completion of the program they had twenty-four weeks of research experience. This tenure in the laboratory was comparable to a full year of graduate level research. Certainly this duration and depth of experience transformed the teachers in some tangible way. It was unlikely that this intensive long-term experience did not influence the teacher’s career as an educator in some manner. If such a lengthy immersion in research failed to reveal any influence, then the relevance of such professional development experiences should be seriously questioned.

This study was also important in determining to what degree science teachers were able to increase their participation in scientific research. Could immersion in a research laboratory with a generalist background allow a teacher to participate in the community as anything more than a skilled technician? The research projects to which the teachers were assigned were high quality investigations with a strong opportunity to produce publishable results. To what degree could a science educator genuinely influence the scope and interpretation of such sophisticated projects? This study hoped to determine the opportunities available to the science teachers and how these opportunities transformed how they viewed and taught science.

Definition of Key Terms

authentic science – learning science in a context of open investigation (Lunsford et al., 2007, p. 540)

community of practice – a set of relations among persons, activity, and world, over time and in relation with other tangential and overlapping communities (Lave & Wenger, 1991, p. 98)

inscription – a written document (figure or diagram) representing a material substance (Latour & Woolgar, 1979, p. 51); signs that are materially embodied in some medium, such as paper or a computer monitor (Roth & McGinn, 1998)

inquiry – a set of interrelated processes by which scientists and students pose questions about the natural world and investigate phenomena. (NRC, 1996, p. 214)

learner – one who participates in the actual practice of an expert, but only to a limited degree and with limited responsibility for the ultimate product as a whole (Lave & Wenger, 1991, p. 15)

learning – becoming able to be involved in new activities, to perform new tasks and functions, to master new understandings; becoming a full participant, a member (Lave & Wenger, 1991, p. 53)

legitimate peripheral participation (LPP) – the process by which newcomers become part of a community of practice (Lave & Wenger, 1991, p. 29)

nature of science (NOS) – the basic tenets of science that guide the construction of new scientific knowledge and distinguish science from pseudoscience

scientific research experiences (SRE) – organized opportunities for preservice and/or inservice science teachers to participate in scientific research for a set period of time.

sensemaking – the process by which scientists make sense of their observations (Latour & Woolgar, 1979, p. 32). the social construction of scientific order out of chaos. (p. 33).

Organization

This dissertation includes five chapters.

Chapter One provides the introduction to the study, statement of the problem, statement of the purpose, research design of the study, assumptions of the study, limitations of the study, importance of the study, and the definitions of key terms.

Chapter Two contains a review of the literature and is reported in three sections. These include legitimate peripheral participation, the nature of science, and scientific research experiences. The section on scientific research experiences is subdivided into two categories: preservice and inservice teachers. A fourth section serves as a summary to draw the literature together.

Chapter Three describes the research design. It begins with the rationale, participants, methodology, research context, research questions, instruments and data collection, and data analysis.

Chapter Four reports the findings of the study. It includes six case studies of teachers created through the triangulation of interview data, analysis of pre and post responses to the VNOS-C (Views of Nature of Science, Form C), and the poster projects. A cross case analysis of the emergent themes concludes the chapter.

Chapter Five closes with conclusions and implications for further research based on the findings.

CHAPTER II

REVIEW OF THE LITERATURE

This chapter synthesizes a review of the literature concerning scientific research experiences for science teachers. The chapter is divided into four major sections. The third section is subdivided into two categories. The sections are as follows:

(1) Legitimate Peripheral Participation (LPP)

(2) The Nature of Science (NOS)

(3) Scientific Research Experiences (SRE)

  (a) Preservice SRE's

  (b) Inservice SRE's

(4) Summary

Legitimate Peripheral Participation

Perhaps the most appropriate lens to employ in the search for understanding how teachers benefit from participation in scientific research experiences is that of legitimate peripheral participation (LPP). Constructed by Lave and Wenger (1991) LPP was defined as “the process by which newcomers become part of a community of practice.” It is a transformation of the framework of situated learning theory. Legitimate peripheral participation furthers the idea of apprenticeship, an ancient idea in education but one saddled with stereotypes and vague definition. LPP provides a structured way to examine how learning occurs through apprenticeships. LPP further evolves the idea of cognitive apprenticeship.

Brown, Collins, and Duglid (1989) wrote at length about cognitive apprenticeship in their seminal paper on situated cognition. Cognitive apprenticeship is a method of teaching that perceived learning as a process of enculturation. Enculturation is accomplished through student participation in authentic practices. Authentic practices are activities that were common to the everyday actions of a person participating in a well-defined field or career. One example of a cognitive apprenticeship in science education would be a summer internship that placed students in groups where they conducted research under the guidance and direction of a professional scientist or highly qualified educator. Through participation in activities and social interaction with other scientists and participating members, the students were enculturated into the research community.

The word cognitive was added by Brown et al. to honor how “apprenticeship techniques actually reach well beyond the physical skills usually associated with apprenticeship to the kinds of cognitive skills more normally associated with conventional schooling.” The authors pointed out that law, medicine, architecture, and business were not merely physical trades yet were all careers that relied on apprenticeships to establish new participants. Curiously the authors neglected to examine teachers’ apprenticeship experiences such as student teaching, internships, and mentor experiences.

Lave and Wenger (1991) conducted ethnographic research on five varied forms of apprenticeship and concluded that even seemingly skills-based apprenticeships were much more than the reduction and transfer of rudimentary procedures. Noting that more recent uses of the term ‘apprenticeship’ were mostly metaphorical, the authors distinguished between their theoretical framework (situated learning) and the historical use of the term apprenticeship (a method of becoming qualified to do a trade). Lave and Wenger also expanded the idea of situated learning from “learning by doing” to “learning is an integral and inseparable aspect of social practice.” (31).

To arrive at legitimate peripheral participation, Lave and Wenger realized two shifts in perspective. The first shift was from apprenticeship, as described historically, to situated learning. This shift came from the authors’ realization that all activity was situated in the use of past and future experiences to interpret the present. The second shift was from situated learning to LPP. Situated learning recognized practice as a significant portion of the process of learning, while LPP perceived learning as “an integral aspect of practice” and thus “learning is an integral part of generative social practice in the lived-in world” (35). No learning occurred outside of practice.

Lave and Wenger’s groundbreaking book on LPP limited itself to contexts outside of traditional schooling. The authors also intentionally stopped short of further defining the “community of practice” and examining the hegemony inherent in bringing new participants into the fold of community. These open-ends for further examination inspired the work I am doing on teachers as researchers in the authentic science laboratory setting.

Legitimate peripheral participation is “a way of understanding learning” (40) as opposed to being “a pedagogical strategy or a teaching technique.” Teaching and learning are decoupled. LPP focuses only on learning, on how the learner learns through their experiences. Learning is defined as increasing one’s participation in a community of practice. The ability of a person to participate in the society serves as a very practical way to quantify what the person learned.

In order to utilize legitimate peripheral participation as a conceptual lens for examining the DOE ACTS program, a well-defined community of practice must be established. This community of practice must be unique from that of research scientists, whose trajectories are focused on advancing within the scientific research community. The teachers do not expect to progress toward full-time research appointments. The community of practice of scientific research experience (SRE) teachers must be limited to the opportunities the teachers have to advance their participation in their mentor’s work.

A second trajectory should also be considered and examined for SRE teachers. One emphasis of the DOE ACTS program was that its participants become leaders within their school science departments and the larger community. Leadership takes many forms, from promotions to supervisory positions to setting the example for inquiry methods of teaching. The laboratory research experience could possibly further teachers within the community of practice constructed around their school of employment.

Legitimate peripheral participation has been employed by several qualitative research studies seeking to better understand how people learn through doing. Lagache (1993) cites LPP as a way to explain why there was a limit to how quickly a community can grow, due to a finite number of ‘old-timers’ available to train ‘newcomers.’ While SRE’s are a form of professional development, the availability of mentor scientists who can do an adequate job of including teachers within their research can be very limited. Thus, long-term SRE’s of the three-year length of the DOE ACTS program are not likely to replace other professional development experiences on a large scale simply because of the limiting factors. This limitation does not prohibit shorter period SRE’s from benefiting more teachers, but the length of time required by the DOE ACTS teachers to become immersed in their mentor scientists’ research does call into question how much a teacher participating in a shorter term SRE can contribute to the design, analysis and sensemaking processes of the scientists’ rsearch.

Fuller and Unwin (2003) pointed out that LPP, as conceived by Lave and Wegner, failed to acknowledge any role of formal educational institutions in apprenticeships. Their case study work focused on the very structured apprenticeship model developed by the United Kingdom to train steel workers. Fuller and Unwin recognized formal education to be a key component in the apprenticeship process, to the point that completion of the program was determined by a very specific list of formal qualification outcomes. Within the DOE ACTS program, the first year education professional development serves to guide the teachers towards finding ways to improve their teaching and integrate their research into their home classrooms. The apprenticeship in the scientist’s laboratories was enhanced through this formal education component.

One contribution of Fuller and Unwin was their proposal of a way to measure the opportunity for a learner to advance their participation within a particular field. They characterized learning environments as expansive or restrictive using a set of criteria standards. A range of opportunity could be established for a company, a school, or any other field relying on apprenticeships in some form. Unfortunately, a range of expansive and restrictive criteria was impossible to identify for this study. First, the lack of direct access to the laboratory inhibited the collection of enough data to make such a determination. Second, there were no formal established standards available against which to measure teachers’ progress. Each teacher advanced within their mentor’s research based on the preferences of mentor, not according to a centralized set of qualifications. Still, each individual teacher’s trajectory could be considered against Fuller and Unwin’s expansive-restrictive continuum in order to better describe the opportunity each teacher had to learn through working in a scientific laboratory.

Nature of Science

There was universal support for the idea that the teaching of school science must be more than the memorization of established facts. In addition to content, recent reform efforts such as Project 2061 (AAAS, 1993) and the National Science Education Standards (NRC, 1996) pushed science classrooms to include opportunities for students to design and conduct inquiry level experiments. In order to accomplish this goal, teachers must help students discover what makes science distinct among the many methods of inquiry. This goal required that teachers help their students construct an understanding of the nature of science. The nature of science (NOS) was described by McComas as

> a fertile hybrid arena which blends aspects of various social studies of science including history, sociology, and philosophy of science combined with research from the cognitive sciences such as psychology into a rich description of what science is, how it works, how scientists operate as a social group, and how society itself both directs and reacts to scientific endeavors. (1998)

Research into NOS was the examination of science from multiple perspectives and contexts in an attempt to understand what science was, is, and will become. It was a description of the nature of the field.

One of the difficulties in teaching about NOS is that there was no complete agreement as to its nature. Opinions abound about how to define science and understand its progression, from Popper's falsification to Kuhn's revolutions to Feyerabend's anarchy. Despite ambiguities and eccentricities left unanswered, there are several aspects of NOS that are well agreed upon. McComas compiled a list of fourteen objectives regarding the nature of science. (See Table 2)

These consensus tenets of the nature of science are in stark contrast to how science is often presented to elementary, middle, and secondary students. For decades, textbooks were criticized for being the primary tool for science teaching.

Table 2. A consensus view of the nature of science objectives extracted from eight international science standards documents

- Scientific knowledge, while durable, has a tentative character.
- Scientific knowledge relies heavily, but not entirely, on observation, experimental evidence, rational arguments, and skepticism.
- There is no one way to do science (therefore, there is no universal step-by-step method).
- Science is an attempt to explain all natural phenomena.
- Laws and theories serve different roles in science, therefore students should note that theories do not become laws even with additional evidence.
- People from all cultures contribute to science.
- New knowledge must be reported clearly and openly.
- Scientists require accurate record-keeping, peer review, and replicability.
- Observations are theory-laden.
- Scientists are creative.
- The history of science reveals both an evolutionary and revolutionary character.
- Science is part of social and cultural traditions.
- Science and technology impact each other.
- Scientific ideas are affected by their social and historical milieu.

(McComas, 1998)

Textbooks focused on mastery of factual content, reducing the learning of science to memorization and experimentation to the verification of well-established principles. Such courses heavily emphasized right and wrong answers with little to no discussion of how scientific theories were developed and almost no reference to how the scientists made their discoveries. Science was portrayed as fact finding with little connection to the processes of science.

Further complicating the problem was that the implementation of inquiry methods in the classroom was weak at best in spite of the best efforts of teacher education programs. Teachers tended to teach as they were taught, so new teachers often must first overcome their own experiences in the science classroom before designing and implementing their own approaches. In order to change, teachers must have established some background and experience in conducting science. Several researchers have reported that participation in scientific research was an effective way to promote inquiry teaching (Raphael, Tobias, & Greenberg, 1999; Westerlund et al., 2002).

Raphael, Tobias, and Greenberg (1999) noted that undergraduate science courses “typically offer short predictable experiments to perform, rather than a chance to design and execute experiments based on real-world problems.” Roth and McGinn (1998) compared the data analysis skills of preservice teachers to those of eighth grade students and to professional scientists. They found that the preservice teachers had more in common with their students than with professional scientists. These findings suggested that traditional university level science coursework did not establish a solid understanding of NOS within teachers that would allow them to conduct or direct authentic scientific research.

Melear, Goodlaxson, Warne, and Hickok (2000) proposed that NOS was best taught through engagement in inquiry, rather than direct instruction. Their approach culminated in the construction of a university-level biology course for prospective teachers that provided preservice teachers with opportunities to design, implement, research, revise inquiry investigations, and report results. Called ‘Just Do It,’ the course required participants to keep laboratory notebooks that chronicled their work and served as a record of their data collection and analysis. Lunsford, Melear, Roth, Perkins, and Hickok (2007) analyzed a set of laboratory notebooks from the course and reported that participants advanced in their ability to produce and transform inscriptions. Brown and Melear (2007) triangulated participants’ laboratory notebooks with interviews and reflective summaries and found that participants acquired scientific skills and content knowledge, but that these experiences did not necessarily translate to their classroom teaching. None of the studies assessed how preservice teachers’ understanding of NOS changed as a result of their participation in inquiry science without direct instruction.

Lederman (1987, 1992, 1995) first proposed the question of how NOS affected classroom practice. His research had yet to reveal any connection between prior coursework and sophistication of understanding the NOS. Nor did his yearlong qualitative observations of five secondary biology teachers show that teacher understanding of NOS correlated with classroom practices. Mellado (1997) reported the same disconnect between NOS and classroom practice in his research of four preservice science teachers during student teaching. Bright and Yore (2002) used pre and post tests with a survey to show that preservice elementary teachers' understanding of NOS could be developed in a science methods course but that classroom observations failed to show that understanding NOS translated into classroom practices.

Lederman and others challenged the assumption that participation in authentic science alone was enough for teachers to infer the nature of science (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002; Bell, Blair, Crawford, & Lederman, 2003; Schwartz, Lederman, & Crawford, 2004). The Views of Nature of Science questionnaire (VNOS) was developed and refined In order to better assess teacher beliefs about the nature of science (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). This open-ended and validated instrument evolved into ten questions, each matched to one or more well-accepted tenets of NOS.

Bell, Blair, Crawford, and Lederman (2003) used a modified form of the VNOS-B to examine the experiences of ten high ability secondary students participating in an eight week science apprenticeship program. They found that while the students showed gains in their understanding of scientific inquiry, the students had no significant improvement in their understanding of NOS. Analysis of the interactions between mentoring scientists and secondary students revealed that little direct instruction on NOS occurred during the apprenticeship. Conversations between scientists and students focused primarily on solving problems related to the projects. One scientist explicitly stated that they chose to let the students "learn about science the way they did, by doing it.” The one student participant who did show an increased understanding of NOS was found to have been especially reflective on her experience throughout the eight weeks. Bell et al. suggested that the outlier showed that scientific research experiences must be coupled with reflection to transform ideas about NOS.

Schwartz, Lederman, and Crawford (2004) observed preservice secondary science teachers enrolled in a science research internship course. Participation in scientific research served as the learning context for teachers to reflect upon the tenets of NOS. The teachers discussed their research and experiences during seminars, where they considered connections between their scientific research and their teaching experiences. Analysis of VNOS pre and post data were triangulated with interviews to understand how NOS knowledge developed and if it was significant in reforming ideas. Preservice teachers who were the most reflective in their journal writings and seminars reported the greatest gains in NOS.

This research into the intersection of research experiences and development of NOS informed the design of the educational professional development portion of the DOE ACTS program. The lead instructor did not agree with the need for focused instruction and reflection on the specific tenets of NOS. One early session of the first year’s weekly educational professional development was dedicated to the tenets of NOS, but no further reflections or discussions of the tenets were facilitated. Several Likert-styled instruments were administered during the first two summers to evaluate change in understanding of the tenets of NOS. These instruments revealed little change in the teachers’ understanding of NOS from the beginning to the end of the first summer. This failure to observe change led to a change in instruments and the inclusion of the VNOS-C as a preassessment for the professional development course for the final two cohorts. In spring 2009, the VNOS-C was administered to cohorts III and IV as a post assessment to measure any possible changes in teachers' understanding of the tenets of NOS.

Scientific Research Experiences

Scientific research experiences (SRE's) for teachers are considered by the National Science Education Standards (1996) to be a key component of professional development. The Standards go so far as to include the ability to participate in actual scientific research as a component of the measure of the competency of a teacher. The reality is that few classroom teachers have or take advantage of opportunities to participate in authentic scientific research, either in their undergraduate or graduate education programs or as part of inservice professional development.

Various opportunities exist for preservice and inservice teachers to participate in research. The time period and level of inquiry of these programs are by no means standard. The literature reports experiences as short as a week or as long as a year. Levels of inquiry range from highly guided to teacher designed. The lack of a standard design makes comparison of SRE's difficult. The only attempt for meta-analysis of multiple SRE's to date is Project SWEPT (Sloane & Young, 1996; Silverstein & Dubner, 2002).

This review of educational research on SRE’s sorted experiences into two categories. Preservice teachers participated in specially designed scientific research courses, often to fulfill a requirement for the completion of an education degree. Inservice teachers were paid assistants in the professional laboratories of practicing scientists. Some SRE’s were very concerned with the teachers’ classrooms, while others were more interested in the final product of the scientific research. No study of an SRE followed a teacher for longer than a year after participation in research, and almost none directly examined the teacher’s classroom.

Preservice Scientific Research Experiences

Five major SRE’s for preservice teachers were reported in the literature. Hemler’s (1997) research focused on a weeklong program at a national observatory. Raphael, Tobias, and Greenberg (1999) examined a summer research experience for preservice science and mathematics teachers. Melear surveyed professors and students (Melear, 1998) then designed, implemented, and refined (Melear et al., 2000; Lunsford et al, 2007; Brown & Melear, 2007) a semester-long inquiry-based biology research experience for education majors. Langford and Huntley (1999) paired preservice middle grades teachers with professional scientists, mathematicians, and educators for a summer research experience. Wilson (2003) created and implemented an inquiry-based astronomy course that provides an opportunity for education majors to produce publishable results. The following paragraphs explain in more detail.

Research Experiences in Teacher Preparation (RETP)

Hemler (1997) reported on a program at the Green Bank Observatory designed to change preservice teachers' perceptions about science and science teaching. The weeklong Research Experiences in Teacher Preparation (RETP) program at the radio observatory preceded the science methods course at two different institutions. Among the objectives of the program were increasing the preservice teachers' understandings of the nature of science, scientific research, and science teaching, improved attitudes toward science research, alleviation of concerns about integrating science research projects into future classroom curriculum, improved science content knowledge, and determination of how successfully the methods course encouraged further change in teachers' perceptions of science and implementation of research teaching methods.

The project was composed of three phases. Phase I was the institute at Green Bank Observatory, where the teachers selected, modified, and implemented research projects provided by the astronomers and additionally received professional development in astronomy content. The teachers also participated in an education hour that related the research experience with the classroom and science education philosophy.

Phase II was the semester long science methods course. Two additional institutions served as control groups for pre and post tests administered to the preservice teachers. During the experimental methods courses, research activities in the classroom continued to be emphasized.

Phase III involved the placement of preservice teachers to do their student teaching under cooperating teachers who were themselves alumni of past professional development experiences at Green Bank Observatory. Classroom observations were made to determine how science research was being used in the classrooms.

Hemler triangulated various pre and post test data sets from each of the three phases of the project with concept maps and teacher journals. The participants affirmed that they had participated in authentic scientific research through the program, overcoming their initial unwillingness, fear of participation, and struggle to become knowledgeable enough to conduct research. The teachers were able to eliminate two common misconceptions about the nature of science: science as an absolute body of knowledge and science as a way of proving theories. No other changes in teachers' understanding of the nature of science were observed. No significant change was found in teachers' attitudes about research or students conducting research in the classroom. This failure was attributed in part to high initial assessment of students conducting research. The science methods course seemed to change little about the teachers' perceptions one way or the other concerning the inclusion of science research.

Future Teachers Research Program (FTRP)

Raphael, Tobias, and Greenberg (1999) conducted a phenomenological study on the Future Teachers Research Program (FTRP) at the University of Arizona, which provided research opportunities for preservice science and mathematics teachers. Students were matched with mentor researchers and assigned meaningful tasks. Seventy-five preservice teachers participated in the summer program over a six year period. Twenty-eight of these were mathematics students and the rest were from physics, chemistry, biology, earth science, or environmental science.

Exit interviews were conducted with each of the participants at the conclusion of their research experience. Each participant submitted a written report summarizing their work. The researchers concluded that the artifacts supported the idea that FTRP yielded positive results. Further research was necessary to establish the scope of these results. Three areas were selected to serve as categories for data analysis:

- how their undergraduate research experience had enhanced their undergraduate or post-baccalaureate education in a valuable way.
- how their undergraduate research experience had contributed to the content and pedagogy of their current teaching assignment.
- how the FTRP had influenced participating science and mathematics faculty.

To address these questions a series of one and a half hour focus group interviews were conducted with nine former participants in FTRP. The focus group data were triangulated with the exit interview data and the written reports using the constant comparative method of Glasser and Strauss. The contributions of the Future Teachers Research Program were summarized in Table 3.

The concern that teacher researchers would leave teaching for research positions was unfounded, though scientists did on rare occasion hint at opportunities to continue with their work. Formative analysis indicated that the program should provide more opportunities for the participants to share their research experiences with one another and to discuss how to share their experiences with their students.

Table 3. Contributions of the University of Arizona's Future Teachers Research Program (Raphael, Tobias, Greenberg, 1999).

Contributions to Teacher Education	Academic research valuable to their education and understanding of science
	Advantage of having done research in a field that was unfamiliar to them.
	Learned how to use scientific instruments (spectroscope, scanning electron microscopes, computer applications)
	Combined scientific research and education through summer
	Increased understanding of the scientific method in action.
Contributions to Content and Pedagogy	Increased the likelihood that they would be able to communicate to their students what professional scientists and mathematicians actually do.
	Gained insights about science they felt had or would impact their pedagogy in the classroom.
	Developed relationships between faculty sponsors and preservice teachers, helping them see scientists as humans and giving insights into what the scientists were like as students.
	Become more closely linked with the scientific research and teaching community, making them more likely to collaborate or inquire of them in the future.
	Learned and implemented new pedagogical strategies as a direct result of the program.
Contributions to Math and Science Faculty	Gained quality research assistants.
	Enlightened faculty to the needs of education majors.
	Encouraged full-time researchers to consider teaching.

Just Do It! Inquiry-based Biology Course

Inspired by her own undergraduate experiences as a laboratory assistant, and in the belief that teachers usually had little opportunity to participate in the processes of science, Melear (1999) surveyed science faculty, inservice teachers, and preservice teachers to gauge the potential for a science research-based experience to be included in the education program. Rather than requiring full laboratory apprenticeships, Melear worked to develop an inquiry-based biology course specifically for preservice teachers (Melear et al., 2000). A botany professor agreed to work with the education department to design and offer a course titled “Teaching Science: Just Do It!” The course targeted preservice teachers who needed an authentic research experience to meet the requirements for a secondary science teaching license in the State of Tennessee. A major goal of the course was to introduce prospective science teachers to successful models for conducting long-term experiments using inquiry methods. The hope was to break the cycle of teachers emulating the contrived experimental (or ‘cookbook’) teaching methods they often experienced in high school and introductory university science courses. With limited guidance from the instructor, the preservice teachers were able to devise and conduct long-term experiments and present results at the conclusion of the course. The researchers reported increased teacher confidence in their ability to conduct authentic research and a positive laboratory experience in general. The teachers were better informed of the processes of science and more capable of designing experiments.

Future offerings of the course were the subject of further research, including the work of Lunsford, Melear, Roth, Perkins, & Hickok (2007) in investigating how the inscriptions recorded in laboratory notebooks increased in sophistication and number throughout the course. The author of this dissertation served as a participant-observer in this course and completed the initial data analysis. Improvements in the quantity and levels of data transformation of inscriptions were evidence that the future teachers had increased their ability to interpret and represent scientific data.

Brown and Melear (2007) examined the laboratory notebooks, reflective summary data resources, and interviews to study three teachers participating in the inquiry-research course. The major result of their qualitative analysis was that the teachers acquired scientific skills and content knowledge. A follow-up interview with the three participants a year following participation in the course revealed little initial implementation of inquiry research designs into the teachers' classrooms. The three teachers cited several time-related constraints that prohibited the implementation of inquiry but none specifically cited a level of discomfort with their ability to conduct inquiry research.

Maryland Collaborative for Teacher Preparation (MCTP)

Langford and Huntley examined the Maryland Collaborative for Teacher Preparation (MCTP) summer research program for preservice middle grades teachers in science and mathematics (1999). Teachers collaborated with professional mathematicians, scientists and educators to do research and curriculum development. Langley and Huntley found that participants suggested the experience was a "fundamentally significant life experience" and because of the program "intend to bring a holistic, conceptually oriented view of mathematics and science to their classrooms." (p. 277)

The MCTP internship program was based on five principles (Fey, 1998). These principles also guided a complete redesign of the entire education program.

1. In mathematics and science content and pedagogy courses, model the practices that future teachers will be expected to employ when they enter the profession.
2. Provide courses and field experiences in order to support the development of understanding and skill in both mathematics and science, so that prospective teachers know and can take advantage of the important connections between the disciplines.
3. Support the development of fluency with modern technologies as standard tools for research and problem solving as well as for imaginative classroom instruction.
4. Prepare prospective teachers to deal with the broad range of students who are in public schools today; give special attention to the understandings and skills needed to help students from diverse cultural backgrounds.
5. Provide placement assistance and sustained support during the critical first years of graduates' induction into the teaching profession.

The internships were not all scientific research settings. Some were internships at informal science centers and businesses. Others were in industrial settings and scientific institutions. Curriculum development was completed following participation in the internship, not during. The primary focus of the time in the internship was to broaden content knowledge. The internships lasted for eight to ten weeks and were full forty hour work weeks. The interns were assigned to a site mentor and kept a journal throughout the experience. Seventeen of the eighteen interns in the 1997 program participated in the study. Of these, three assisted in science research, one in mathematics research, and one in educational research. The others worked in curriculum development, taught science, or participated in naturalist interpretation.

Data collected during the summer was primarily qualitative. Responses to an electronic mailing list, journal entries, and other artifacts were reviewed multiple times to generate categories and themes. A Likert-scale survey was adapted from an existing instrument used to track teachers' changes in knowledge and beliefs and administered as a pre and post test at the beginning and conclusion of the internships. Student responses to the pre and post were matched to one another to see how each individual's perceptions changed. A triangulation of the data generated three themes: (a) the nature and processes of mathematics and science, (b) the teaching of mathematics and science, and (c) the nature of the professional workplace.

For some, the processes of the laboratory were boring, repetitive, and frustrating. Others found the experience exciting and engaging. They gained insights into the dedication required to accomplish research and the tentative nature of scientific knowledge. The second theme suggested that shifts in perception of science process were paralleled by shifts in beliefs about teaching and learning. The interns grew to see teachers as "curious learners" and to realize "that learning is a self-directed activity" (Langford & Huntley, 1999, p. 289). The workplace was found to be fast-paced and stressful, and the interns reported that no one worked the minimum forty hours, nor did they complain about working extra. The interns also reported a new ability to identify scientists as people.

Other qualitative results gleaned from the data suggested that the interns found a sense of pride by having authentic experiences in their fields. Some were able to publish their research. All seemed to gain confidence in having done real work in the field, eliminating any question anyone could have about their competence as a science professional. Langford and Huntley reported a failure to understand how the program translated to the classroom and expressed a desire to add a classroom implementation component.

The Binary Star project

The success of Melear's "Just Do It" course inspired Wilson (2003) to design and implement an inquiry-based astronomy course for preservice science teachers. The course gave teachers access to an observatory to take measurements of binary stars and report them to the Naval Observatory database for publication. Through guided inquiry, the teachers chose candidates and learned scientific techniques for making measurements.

Participation in The Binary Star Project course showed positive changes in teachers' understanding of the nature of science, especially in aspects of tentativeness, empirical, social and cultural embeddedness, scientific methodology, the difference between data and evidence, and data analysis (Wilson, 2003). Limitations of the study prohibited any measurement of transfer to the teachers' future science classrooms.

Three of the seven teachers reported positive changes in their attitudes toward the inclusion of scientific investigations in their classrooms.

Scientific Research Experiences for Inservice Teachers

There are at least eight major publications reporting on SRE's for inservice teachers. Two of these (Sloane & Young, 1996; Silverstein & Dubner, 2002) were comparisons of multiple SRE's using primarily quantitative methods. The remaining eight used primarily qualitative methods or surveys to attempt to understand teachers' experiences on many different levels. The next few paragraphs summarized each research project, beginning with the two examinations of scientific work experience programs for teachers and then followed by the others in chronological order.

Science Work Experience Programs (SWEPs) circa 1994

Discussions between program managers and funders at the 1994 conference of Scientific Work Experience Programs (SWEP) led to the creation of a survey to evaluate collectively programs that provide teachers with scientific research experiences (Sloane & Young, 1996). The SWEP survey does not give insights into the specific results of each site but was significant because it revealed the criteria each site used to declare success or failure. The survey was designed to:

- Provide information to the SWEP community on current practices in evaluation.
- Determine if there is enough common ground (in project purposes, evaluation requirements, and existing strategies) to proceed with

plans for a national evaluation, and/or the development of a common set of procedures that local projects might use.

- Offer some suggestions on ways the survey and the survey results might guide further discussions of local or national evaluation strategies, and some methods that might be considered in such efforts. (5)

Thirty-five of an estimated fifty functioning SWEPs returned the surveys. Seventeen of the programs were in industry, sixteen in university laboratories, and two classified as “other.” Seventeen of the programs employed more than fifteen teachers, and twenty-six programs were older than five years.

The analysis of the survey revealed that a majority of the program evaluations of each SWEP were concerned with “attainment of goals,” “implementation of project activities,” and “teacher outcomes.” Only two or three specifically listed “classroom transfer,” “student outcomes,” or “sponsor outcomes” in their evaluations. The absence of these suggest that SWEPs are more interested in the teachers accomplishing the research and gaining something unspecific rather than the experience changing the teachers’ classroom or impacting the host organizations in a beneficial way.

The researchers argued different methods of collective assessment, settling on cluster sampling. They acknowledged that an assessment of the teachers within each site would be impossible for a collective research project, but did pass their recommendations on to the members at the next conference. These recommendations eventually led to a $1.6 billion grant from the National Science Foundation to study eight SWEPTs (Science Work Experiences for Teachers).

Science Work Experience Programs for Teachers (SWEPTs) final report – 2002

Silverstein and Dubner (2002) completed a four year, NSF-funded comparison study of eight SWEPTs in order to address several questions about research programs for teachers. The SWEPT study remains as the largest sample and most rigorous quantitative research project that attempted to measure the impact on teachers interning in scientific laboratories to date. The primary question was whether teacher participation in a SWEPT affected student achievement and attitudes in science and mathematics. Silverstein and Dubner used a quasi-experimental design and a series of surveys and student aptitude tests to compare 59 math and science teachers who successfully participated in one of eight SWEPT sites in the summer of 1999 or 2000 to a teacher of comparable experience and skill who did not participate in research that summer. The study addressed four specific questions:

1. Did teacher participation in a SWEPT have a positive impact on student interest and achievement in science?
2. Are there any characteristics that distinguish teachers who elect to participate in a SWEPT?
3. Did SWEPTs provide participating teachers with experiences that might be expected to affect their classroom and teaching practices?
4. What did mentors report about their SWEPT experiences?

The researchers concluded that teacher participation led to students having statistically significant cognitive gains in content specific post tests at the $p<.05$ level as compared to teachers who did not participate in SWEPT. The researchers failed to find any statistically significant differences between teachers participating in SWEPT and their comparison teachers. The researchers found SWEPT participants more likely to use inquiry-based constructivist methods in their classrooms. A very important finding was that 95% of the mentor scientists agreed or strongly agreed that the SWEPT experience was beneficial for teachers and 86% agreed or strongly agreed that the SWEPT experience was worthwhile for mentors.

Science Teachers as Research Scientists (STARS)

One of the early papers examining the benefits of teachers as researchers is Gottfried's report on the STARS (science teachers as research scientists) program at the University of Missouri-St. Louis (1993). Over the course of three summers, seventeen science teachers from St. Louis schools interned with biology, chemistry, and physics faculty members at the aforementioned university. Friday mornings were dedicated to curriculum development workshops.

The STARS program had six objectives: (1) provide teachers with experience in scientific research design and experimentation, (2) enhance teachers' understanding of the nature of science, (3) upgrade teachers' science content knowledge and process skills, (4) increase teachers' knowledge regarding applications of science in the workplace, (5) upgrade teachers' skills in the implementation of learning cycle and inquiry strategies in science teaching, and (6) guide teachers in the preparation of laboratory-based curriculum problems based on their research experiences.

The accomplishment of these objectives was assessed by qualitative and quantitative methods. At the time of the publication of the article the qualitative research was being coded and thus results were unavailable. Four instruments of interest were deployed following the first summer. Two were generated and validated by other researchers: TIPS (The Test of Integrated Process Skills) and the Science Classroom Activity Checklist. A pair of teacher questionnaires was generated by the project director, both using Likert-scales with room for open responses. One survey was administered during the last curriculum development session and the other six months later.

The instruments failed to yield anything of statistical significance. Almost half of the teachers scored better than eighty percent on the pretest thirty-six item TIPS survey of process skill attainment, leaving little room for mean improvement in the posttest. The Science Classroom Activity Checklist, administered to the teacher's classes before and after participating in the program, yielded no statistically significant changes in the students' perceptions of seven categories of the classroom. The researchers believed that changes were either immeasurable or failed to be detected by the instrument. Analysis of the questionnaires revealed no significant increase in the amount of time spent on laboratory and hands-on activities. In the conclusion, Gottfried acknowledged that the teachers perceived themselves to have more process skills and implemented more hands-on activities, though the statistical data collected did not support their perceptions.

Southeastern Regional Vision for Education (SERVE)

The Eisenhower Consortium @ SERVE (Southeastern Regional Vision for Education) partnered with Florida State University to place five middle and two elementary grades teachers from a doctoral cohort in science education in scientific research positions for a semester (Kielborn & Gilmer, 1999). The teachers' experiences in the Teachers Learning Inquiry through Scientific Research (TLISR) program were chronicled in the nine chapters of *Meaningful Science: Teachers Doing Inquiry + Teaching Science*.

Gilmer served as the principle investigator, employing qualitative research methods to examine the gains of the participants. Sources of data included field notes, email correspondence between teachers and research mentors, professional papers written by the teachers, science research reports, teacher portfolios, and visits to the research sites and the teachers' classrooms. Three questions guided her research:

- As teachers construct new understandings of the nature of scientific inquiry and processes of science through authentic research, do they begin to think differently about scientific inquiry and how they might teach science?
- Are teachers starting to teach science differently after they have actively participated in scientific research?

- Are K-8 students starting to engage more in inquiry-based science when it is taught by teachers who have experienced authentic scientific research? (Kielborn & Gilmer, 1999, p. 12)

Kielborn and Gilmer concluded that “co-participation and a shared discourse were critical in a contextual learning experience in scientific research (p. 22).” Shared discourse afforded the teachers a chance to participate in the formal language and methods of science as well as experience the culture of science. Rather than view science as facts, the teachers experienced the process by which observations become scientific understandings. After completing the program the teachers presented on their research experiences at educational and scientific conferences. Contextual learning allowed the teachers to realize the tentative nature of science and how scientific knowledge was constructed rather than discovered as absolute fact.

Kielborn and Gilmer stopped short of explaining how an improved understanding of scientific inquiry translated to the teachers’ classrooms, though they were confident that the teachers were more involved in “real science” and that the teachers were designing inquiry opportunities that allowed students to examine their own research questions. Thus the teachers created an opportunity for their students to learn science contextually. Kielborn and Gilmer touted the relationships built between the host institutions and the teachers, though she did not specify how, other than to say that the hosts improved their understanding of teachers’ needs.

Science/Math/Technology Education Institute (SMTEI)

Westerlund, Garcia, Koke, and Mason (2002) reported the results of a phenomenological study of twenty-three secondary school teachers who participated in an eight-week summer institute at a large university. The study included observations of the teachers' classrooms the next fall to determine how the research experience influenced their use of inquiry methods. The research study was designed around three primary questions:

1. What is the nature of a summer research experience for teachers?
2. What features indicate that secondary school teachers have been provided with an authentic scientific research experience during the summer?
3. How does the summer research experience affect teachers and their students in the academic year following the summer research experience? (p. 66)

The researchers compiled data from several sources and analyzed it using qualitative methods to authenticate the research experiences and to identify how the experience impacted the teachers and their students the next academic year. The research impacted the classroom through increased teacher content knowledge, communication with mentor scientists (often to the scientists' involvement with the classes in a direct way), and increased use of inquiry science activities in the classroom. Also noted through the study was a rejuvenation of the teachers' interest in teaching science to their students. The researchers confirmed the increased student respect for teachers who participated in authentic scientific research.

Westerlund et al. also composed four evidence-based recommendations for establishing summer institutes for teachers. These included:

1. Design a summer institute that provides sufficient time for teachers to be actively engaged in scientific research. Allow teachers to become active scientific researchers for ninety-five percent of their time without the distraction of other responsibilities.
2. Provide a forum in early spring in which teachers can meet their mentors, other teacher-researchers and program staff and can become acquainted with the research site.
3. Require that teachers attend a weekly two-hour meeting with the other teacher-researchers and program staff. In this meeting, teachers should discuss ideas about teaching science, their research, and ways to implement student research into their classrooms.
4. Require teachers to present their research at an end-of-summer poster session. (p. 80)

Nevada Science Teacher Enhancement Program (N-STEP)

The *Journal of Geoscience Education* published a special issue in 2003 to examine effective partnerships in geoscience research between schools and undergraduate science institutions. Two articles contributed to the cause of understanding the impact of scientific research experiences on teachers. Buck wrote about the Nevada Science Teacher Enhancement Program (N-STEP) and Jarrett and Burnley wrote about a summer geoscience research program for teachers sponsored by

Georgia State University and funded by the National Science Foundation Research Experiences for Undergraduates (NSF-REU) initiative.

N-STEP paired teachers and high school students with researchers at eight work sites over a period of three years. The primary focus of N-STEP was to “increase teachers’ science content knowledge and understanding of research methods to help improve their own teaching.” The teachers’ research experience was embedded in a nine-month program that included formal lessons in research context and pre and post field research learning. Teachers could earn four credit hours through the University of Nevada Las Vegas. Each team wrote a research paper, prepared a poster, and gave an oral presentation of their work.

A qualitative formative evaluation of teacher gains suggested that the teachers “voiced high regard for the scientists, enjoyed positive experiences in meeting other students and teachers, had good collegial relations with scientists and graduate students, learned a great deal of discipline specific science content, and strongly appreciated the opportunity to conducting authentic research” (Buck, 2003, p. 50). The summative evaluation included two surveys: the Beliefs About Science and School Science Questionnaire (BASSSQ) (Aldridge, Taylor & Chen, 1997) and the Science Teaching Efficacy Beliefs Inventory, form B (STEBI-B) (Enochs & Riggs, 1990). The BASSSQ investigated teacher perceptions of the nature of scientific research, while the STEBI-B monitored teachers’ self efficacy. The BASSSQ was administered as a pre and post test to the research experience, and again after the students completed their posters and projects. No significant differences were found at the $p>.05$ level. Either the teachers had a strong prior understanding of the nature of science or the program did not impact their perceptions. The STEBI-B was administered at three different times in the course. No statistically significant differences were found, suggesting that the research experience did little to change how the teachers felt about their teaching abilities or their ability to influence students.

National Science Foundation – Research Experiences for Undergraduates (NSF-REU)

The NSF-REU program at Georgia State University paired inservice teachers with undergraduate science majors and science faculty in four research teams. The teams conducted research for approximately forty hours a week for eight weeks. The teachers were surveyed at the beginning, middle, and end of the program. No statistically significant increase in the participants' interest in science was found, perceivably because it was high to begin with. The participants reported that they were "learning a massive amount," "learning good research techniques," and that they "like the culture" of doing research. Interestingly enough, one of the teachers reported that they were now considering a return to graduate school to further study geology. The fear of teachers abandoning the classroom to do research because of such programs was often mentioned but in the literature reviewed for this paper this was the first time a teacher was inspired to actually leave the teaching profession.

Teacher Enhancement in Pedagogy and Ecology (TEPE) project

Drayton & Falk (2006) investigated the TEPE project which recruited a total of 240 high school teachers from three states and placed them in yearlong research cohorts over a period of three years. The cohorts were composed of groups of four teachers who applied as a unit to conduct research in collaboration with a professional ecologist. The teachers participated in an intensive summer workshop where they developed a plan for research in conjunction with their assigned ecologist.

The purpose of the research was to identify key dimensions to successful teacher-scientist collaboration. Five key dimensions were constructed through a qualitative analysis of surveys and artifacts and then reviewed by focus groups to member check their accuracy. These included:

(1) Whose question was being investigated?

(2) Was the focus primarily on data collection or data analysis?

(3) Was the research based on the ecologist's area of expertise or the teachers' interests?

(4) Was the focus primarily on the teachers' learning or on their students' classroom learning?

(5) Who is the research for? Who is the audience?

Drayton and Falk then illustrated the usefulness of the dimensions understanding teacher-scientist interactions in three case studies.

It was important to note that the researchers found no single set of responses to the dimensions that suggested success or failure. Rather, it was matching scientists and teachers with similar expectations for the research that made all the difference. The negotiation of the terms of the research project and achieving consensus led teachers to declare their research experiences successful. Teachers required a sense of ownership in the inquiry project and a clear sense of purpose for their research.

Summary

Scientific research experiences for teachers were considered a necessity by both of the national attempts to reform the preparation and professional development of science teachers. Acknowledging the specific changes in teachers as a result of participation in SRE's was more difficult. Several common realizations emerged from a thorough review of the research. Legitimate peripheral participation served as a conceptual lens through which SRE's may be examined. As teachers became enculturated in a professional laboratory, one of the most obvious dimensions to examine was the teachers' understanding of NOS. But LPP became a tool for examining how teachers' research experience and other professional development impacted their classroom teaching and their professional career. Though a handful of the SRE's in the literature warned that sometimes research experiences tempted teachers to leave the classroom, few left to become professional scientists.

Research into scientific research experiences for teachers attempted to understand how to enhance these experiences. Drayton and Falk (2006) identified five dimensions to be negotiated between mentor scientist and teacher in order for research experiences to be successful. Westerlund et al. (2002) compiled four evidence-based recommendations to guide others in establishing future summer research programs for teachers.

Other researchers focused more on what teachers learned through participation in research. Many researchers reported increases in content knowledge (Sloane & Young, 1996; Hemler, 1997; Langford & Huntley, 1999; Raphael, Tobias, & Greenberg, 1999; Melear et al., 2000; Westerlund et al., 2002; Buck, 2003; Jarrett & Burnley, 2003; Wilson, 2003; Drayton & Falk, 2006).

How gains in teacher content knowledge translated to the classroom was tenuous and in need of further examination. Several programs (Gottfried, 1993; Hemler, 1997; Langford & Huntley, 1999; Westerlund et al., 2002) dedicated time to developing new curriculum and sought ways to include elements of the experience in the teachers' classrooms, as did the DOE ACTS program. Preservice SRE's (Melear, 2000; Wilson, 2003) considered their entire research courses to be a model for classroom research. Several researchers (Raphael, Tobias, & Greenberg, 1999; Westerlund et al., 2002; Drayton & Falk, 2006) claimed increased content knowledge translated into shifts toward inquiry-based pedagogy. Others (Hemler, 1997; Langford & Huntley, 1999; Melear et al., 2000; Drayton & Falk, 2006) reported the content knowledge improved teacher self-confidence and increased the teachers' status in the eyes of their students (Hemler, 1997; Langford & Huntley, 1999; Drayton & Falk, 2006). Many teachers' interest in science increased through participation in authentic scientific research (Langford & Huntley, 1999; Melear et al., 2000; Jarrett & Burnley, 2003; Drayton & Falk, 2006). Westerlund et al. (2002) observed that teachers were “rejuvenated” through their experiences.

Gottfried (1993), Hemler (1997), Westerlund et al. (2002), and Silverstein and Dubner (2002) were the only researchers who gathered data on the teachers’ students during the course of the following school year. These researchers reported mixed results in how the research experience translated to the classroom. Gottfried discerned no difference in students’ perception of how much time they spent conducting laboratory or hands-on activities. Westerlund found an increase in inquiry-based activity, as did Silverstein and Dubner, who went a step further and compared student performance in courses taught by participants and a comparable teacher at the same school. Silverstein and Dubner reported a positive correlation between the participation of teachers in SRE’s and student test scores.

From these findings it was determined that six dimensions of SRE’s, including trajectory of participation, content knowledge development, mentor relationships, NOS, teacher confidence, and classroom practice would be investigated. These dimensions were included within the three research questions guiding this qualitative study.

CHAPTER III

MATERIALS AND METHODS

Research Context

The subjects of this study were six teachers participating in the Department of Energy's Academy Creating Teacher Scientists (DOE ACTS) at Oak Ridge National Laboratory from 2006 to 2009. Beginning in 2004, teachers from across the United States were invited to apply for a paid three summer internship at the laboratory. A program director from ORAU facilitated the teacher's research appointments. Each teacher was assigned to a professional research scientist who served as their mentor for the summer. Teachers were encouraged to spend all three summers with the same mentor, but several were unable to do so for a variety of reasons and were assigned other mentors as necessary.

An overarching theme of the program was finding ways to assist the teachers in connecting their research experiences to their classrooms. Professional development to this end was an integral component of each summer of research. First year teachers participated in a weekly three-hour educational professional development session. Topics included navigating national science standards, designing inquiry-based student activities, keeping a laboratory notebook, and finding ways to share their research experiences with their students. These sessions were designed and taught by the education faculty of a local university and included the author as a guest instructor.

The special topic for the second research summer was data-driven decision making. During the course of three sessions, led by a retired high school principal, teachers were trained in methods of collecting and analyzing data for the purpose of making informed instructional decisions. Formative and summative assessment options were considered.

The focus of the third summer's professional development was persuasive presentation. An outside consultant led two eight-hour sessions, one on speech writing and the other on speech delivery. The program director led a single five-hour session on technical writing.

Teachers assisted the mentors with their ongoing research. Throughout the summer the teachers followed procedures, collected data, and developed a poster presentation of their summer's work. These posters were shared in an informal poster session open to all at the laboratory. Members from the active cohorts shared this experience during the final week of their appointments.

In addition to their posters the teachers were required to complete two education modules. The modules were intended to serve as a structure for sharing the teachers' research with students. These modules were written during the first summer and revised and modified each subsequent summer. Teachers were asked to collect and analyze student data as part of their reflection on the module.

Rationale

The National Science Education Standards (National Research Council, 1996) recommended that teachers engage in professional development that included participation in laboratory research. Fifteen years of education research have yielded some details about the value of participation in authentic research that led teachers

- to increase the depth of their content knowledge (Sloane & Young, 1996; Hemler, 1997; Langford & Hunley, 1999; Raphael, Tobias, & Greenberg, 1999; Melear et al., 2000; Westerlund et al., 2002; Buck, 2003, Jarrett & Burnley, 2003; Wilson, 2003; Drayton & Falk, 2006).
- to gain status in their schools with their students (Hemler, 1997; Langford & Hunley, 1999; Drayton & Falk, 2006).
- to learn new science skills (Raphael, Tobias, & Greenberg, 1999; Melear et al., 2000; Jarrett & Burnley, 2003; Wilson, 2003).

No study has examined growth in the teachers' ability to contribute to the mentors' research projects. Understanding how repeated experiences added to the teachers' capacity to conduct research in the professional laboratory and with their students was one of the aims of this study.

Another point of interest was to understand how teachers' perceptions of NOS changed through repetitious research experiences. Prior research has been inconclusive as to how teachers' understanding of NOS is impacted. Some studies reported modest gains (Hemler, 1997; Kielborn & Gilmer, 1999), but most reported that teachers participating in research programs begin with a higher than average conception of NOS and have little room for improvement (Gottfried, 1993; Hemler, 1997). Schwartz, Lederman, and Crawford (2004) reported that participation in research without reflection on the tenets of the NOS failed to elicit any transformation in teachers' conceptions.

A third point of interest was to understand how scientific research experiences directly and indirectly transferred to the classroom. While one pair of researchers constructed an approach they believed showed the influence on student performance (Silverstein & Dubner, 2002), no formal investigation using pre and post observations and analysis of teachers' classrooms was reported in the literature. Direct observation of teachers in their classroom was beyond the scope of this study but interviews were were designed to elicit information about teachers' changes in instructional strategies as a result of their experiences in the laboratory.

This study was unique in its examination of teachers participating in three consecutive summers of research. No other educational research has reported more than two consecutive summers (Drayton & Falk, 2006) and participation in a second summer was optional for those teachers.

Research Questions

The following research questions guided this investigation:

1. To what degree were the teachers able to increase their participation, thus becoming more valuable to pursuing original research designs and sensemaking of data?
2. To what degree were the teachers learning about the nature of science through participation in scientific research?
3. How did participation in authentic scientific research impacting the teachers' classrooms?

Participants

Six participants, three each from the third and fourth cohorts, were chosen to be the subject of case study. They were selected from among the seventeen members of cohorts three and four because all six had completed three consecutive summers of research in the program and they were the only teachers who completed the post VNOS-C assessment and thus were the only ones who had participated in all phases of the data collection. Teachers from the first two cohorts were not selected for case study because the VNOS-C was not administered to them as a preassessment. Table 4 summarized the teachers' research experiences in context.

All of the study participants in Cohorts III and IV were Caucasian. Each of the three teachers from Cohort III was female and had taught more than fifteen years. Two of the three teachers from Cohort IV were male, one female. None of the members of

Table 4. Research Experiences of Participants

Name[a]	Cohort	Prior Research Experience	Internship Research Area (Year) Grade Level; Content Expertise of Program
Myra	III	MS Biology; thesis on salamanders	Genomics (1,2), aquatics (3); secondary (9-12); biology, anatomy & physiology
Connie	III	Industrial chemist; product development	Materials Science (1,2,3); middle (6-8); chemistry/physical science
Sierra	III	None	Chemical Sciences (1,2,3); secondary (9-12); chemistry
David	IV	Teacher research experiences in Thailand, and the Green Bank Observatory	Biological Sciences (1), Astrophysics (2,3); secondary (9-12); astronomy, biology
Betty	IV	Industrial chemist;	Biological Sciences (1), Energy & Transportation Sciences (2,3); secondary (9-12); chemistry
Joseph	IV	None	Computer Sciences (1,2), Material science (3); secondary (9-12); mathematics

[a] Pseudonym

Cohort IV had more than ten years of classroom experience. One of the Cohort III teachers was from Kentucky. One member of Cohort IV was from Ohio. All of the other teachers selected for case study were from middle or east Tennessee.

Only one teacher taught at the middle school level. She had experience teaching at the secondary level prior to her assignment to the middle school. Two of the teachers from Cohort III had backgrounds in chemistry. The other had a background in biology.

One member of Cohort IV had a background in mathematics and computer science, another in chemistry, and the third in biology and astronomy.

Methodology

This study meets the criteria for a participant observation multiple case study as described by Hatch (2000). The study is a participant observation because of the familiarity of the author with the teachers and their research. He first taught and observed each cohort of teachers as a guest instructor and assistant for the weekly educational professional development course. The author attended the annual end of the year poster sessions. Additionally, the author attended talks given by the mentoring scientists and their teacher protégés to audiences of teachers participating in various other professional development opportunities. The author also conducted semi-structured interviews of approximately forty-five minutes in length with fifteen participants from across the four cohorts. Many informal conversations with teachers occurred throughout their time at the laboratory, as well as occasional electronic communication. Unfortunately security restrictions prohibited direct observation of the teachers as they worked in the laboratory, an unfortunate but understandable consequence of the highly sensitive nature of the work being conducted in parts of the national laboratory.

This study could also be considered a holistic multiple case design as described by Yin (2003). The six case studies collectively examined the experiences of teachers engaged in apprenticeships with mentoring scientists at Oak Ridge National Laboratory through the DOE ACTS program. The unit of analysis for each case study was defined to be the individual teacher. Rather than considering the six cases to be a convenience sample, this study followed Yin's (2003) recommendation to aim for replication. The selected cases yielded literal replications in the sense that similar results were observed across each of the cases.

An assortment of artifacts was collected throughout the five summers working with the teachers during the educational professional development course. Six survey instruments collected open-ended and Likert-scale information regarding the teachers' perceptions of the nature of science and scientific research and how it changed from the first week to the final week of their first summer in the program. These artifacts were not included in this study but served to inform the early direction and future data collection of the study. Appendix A includes a chart organizing these instruments and their functions. A cursory analysis of the data from the first and second cohorts revealed that the teachers' understanding of NOS was unchanged from the beginning to the end of the summer. In order to further probe the teachers' ideas about NOS, the VNOS-C was added to the battery of instruments administered on the first day of the professional development for cohorts III and IV.

Three critical data sources were selected to inform this qualitative study. These artifacts included the teachers' written responses to the VNOS-C during their first year, their electronic responses to the VNOS-C after they completed their research assignments, semi-structured open-ended interviews conducted in summer and autumn

Table 5. Instruments Used to Inform the Study

Data Source	When	Research Question	Analysis
Interviews	post	1, 3	QDA Miner
VNOS-C	pre/post	2	Matrix
Posters	post/post	1	Rubric

2008 with participants from all four cohorts, and photographs of the 2007 and 2008 poster sessions. See Table 5.

A cross case analysis of the six case studies revealed several common themes about three important aspects of the teachers' experience: how teachers' increased their ability to participate in scientific research over the course of three consecutive summers, how teachers' views of the nature of science (NOS) were impacted through their immersion in a professional laboratory, and how teachers' classrooms and professional lives were impacted as a result of their participation in DOE ACTS.

Instruments and Data Sources

Semi-Structured Interviews

Semi-structured interviews were conducted with fifteen participants from across the four cohorts during the summer of 2008. By that summer all members of cohorts I and II had completed their three years at the laboratory or dropped out of the program. Members of cohort III were completing the final year of their research appointments while those of cohort IV were finishing their second summer at the laboratory.

Communications were exchanged between the author and members of cohort IV during fall 2009 in order to inform this study about the cohort IV's final year at the laboratory.

The original list of twelve questions is included in Appendix B. The interview questions were designed in the spirit of Strauss, Schatzman, Bucher, and Sabshin's (1981) four major categories of questions, as referenced by Merriam (1998). These categories included hypothetical, devil's advocate, ideal position, and interpretive questions.

The twelve questions were created to elicit information about the teachers' general experiences at the laboratory, how much latitude they received to pursue their own ideas for research, their relationship with their mentor scientist, and the consequences of their experiences on their classroom teaching. The interviews informed the first research question with self-reported responses about how the teachers were able to increase their participation. The interviews informed the third research question by providing important details about the impact of the research experience on the teachers' classrooms.

The interviews provided key insights into the knowledge the teachers gained from participation in the research program. These gains included increased understanding of the established scientific principles, or facts, guiding the normal science in which they were immersed and the techniques (use of laboratory equipment, typical experimental procedures, and methods of interpretation) necessary to conduct scientific investigations. Interviews and posters provided information about teachers' increased knowledge that would have been very difficult to obtain through pre/post testing.

The trajectory of participation was refined to the processes necessary to become an informed teacher, knowledgeable about the skills, techniques, and methods employed by professional scientists and capable of facilitating scientific research in the form of short and long term inquiry investigations in their classrooms. This framework clarified what it meant for teachers to learn through participation. Learning was defined as any increase in their participation in the laboratory that resulted in becoming a more informed teacher.

After the process of interviewing teachers began, the author noticed that he found himself asking some of the same follow-up questions of each participant. Thus the list of interview questions was revised to include these questions. This list is included in Appendix C. A map of how each interview question corresponds to the research questions is included in Appendix D.

Views of the Nature of Science, Form C

The Views of the Nature of Science Form C (VNOS-C) is a ten question interview protocol developed by Lederman, Abd-El Khalick, Bell, and Schwartz (2002). The VNOS-C was designed to elicit a rich understanding of the teachers' understanding of the key elements of the nature of science, including the tentative nature of theory, the difference between theory and law, and the role of creativity and imagination in science as a human invention.

The instrument was designed in response to several calls for a new instrument that satisfied three limitations of previous attempts. First, the instrument must consider the respondents’ rationale for selecting a position rather than automatically assume that the response is supported by the same understandings as those of the developers. The new instrument must not reflect the NOS view and biases of instruments’ developers. Finally participants must not be sorted into only two categories: adequate or inadequate. Over the course of twelve years the instrument evolved from the VNOS-A, a seven question survey, to the VNOS-B and finally to the ten question VNOS-C.

During the first professional development session for cohorts III and IV, the teachers were asked to write their response to each of the questions of the VNOS-C. These written responses served as a pretest of the teachers’ understanding of the tenets of the nature of science. No follow-up interviews were conducted to clarify these responses.

The VNOS-C was adapted into an Internet survey in spring 2009. This adaptation allowed teachers to respond to the VNOS-C at their convenience and submit their answers electronically. The questions in the survey are identical to those of the VNOS-C, with some minor adjustments to better facilitate follow-up questions to those with multiple parts. Appendix F includes the questions and follow-up questions used in the online version. All members of cohorts III and IV (who had participated in the pretest during their first summer) received multiple email invitations to contribute their responses. After several follow-up contacts, six of the fifteen teachers who consented to participate in this study completed the online survey.

Poster Presentations

A third source of data informing this study were photographs of the posters presented by the teachers at the conclusion of the summers of 2007 and 2008. These data were examined and triangulated with the interviews to develop a broader description of the teachers' research experiences. Three of the six case study participants presented one poster at each session for a total of two each. One case study participant was part of two posters during 2008, one as lead author and another as second author. Another participant failed to present a poster in 2008. The other participant declined to permit her poster project to be photographed at the request of her mentor. It contained unpublished results regarding very experimental techniques and he feared their accidental disclosure to competing research groups. Permission from the mentor scientists to reproduce the posters for inclusion in this dissertation was not obtained and so no sample posters are included in the appendices.

The posters themselves were intended to highlight the research activities of each teacher. The teacher was listed as first author on each poster, followed by any contributing teacher researchers and finally by the mentor scientist. The posters were produced digitally and professionally printed. The posters were displayed for approximately an hour on easels set up in the lobby of a building across from the laboratory's visitor center. Teachers stood beside their posters to answer any questions from their peers, other mentors, program personnel, and other scientists passing by. At the conclusion of the session the teachers took their posters to share with their students and with any other group of people to which they might present their work to in the future, such as civic groups, school faculties, or professional conferences.

A rubric was created and used to analyze the posters (see Appendix H). The rubric was designed to facilitate the comparison of the elements of the teachers' posters. Five dimensions were examined: year, title, author or authors, section headings, and inscriptions. The rubric provided a space for notes to be recorded. Legitimate peripheral participation provided a framework for data analysis. Increases in the number, quantity, and quality of section headings and images from year to year and the quality and detail of the inscriptions served as evidence of increased participation, or learning. The posters also reinforced the descriptions of the research projects in the case studies.

Other Data Sources

Several other artifacts were collected over the course of five years and referenced at various points in time to inform this study. The program handbook (Department of Energy, 2006) and a presentation by the program director were critical to the author's understanding of the goals, expectations, and products the teachers were expected to complete during their tenure of research. In addition the author attended presentations by the mentor scientists and teachers whenever possible to provide further specifics regarding the teachers' research areas. Several emails were exchanged between individual teachers and the author. Many informal conversations happened throughout the summers with participating teachers at the laboratory, professional conferences, and other events.

Data Analysis

Three research questions served as the foundation for this study. This report of the data analysis was organized around each of the three questions. The following sections describe how each data source was analyzed in the attempt to answer the research questions.

Teachers' Legitimate Peripheral Participation in the Research Laboratory

The primary source that informed the first research question was the interview data. Interviews were recorded during a five month period from July to November 2009 and transcribed. Cohort III participants were finishing their final summer, while Cohort IV participants were completing their second summer of research. QDA Miner was used to analyze the textual data by employing a typological approach to data analysis, (Hatch, 2002, LeCompte & Preissle, 1993). Three main categories of codes were constructed, one for each of the three primary research questions: legitimate peripheral participation, nature of science, and classroom.

The first category of codes concerned the legitimate peripheral participation of the teachers. A tentative set of code subcategories was constructed to facilitate the interview coding process. Throughout the first review of the data, new subcategories were added and previous subcategories modified. Some of these categories are included in Appendix G.

The teachers' poster presentations from 2007 and 2008 were used to provide greater insight into the teachers' LPP. Digital photographs of the second and third year posters from Cohort III and the first and second year posters from Cohort II were examined individually. Appendix H includes the rubric used for evaluating details of the posters. Of interest were the title, authors, sections included in the poster (abstract, objective, procedure, methods, conclusions, implications, acknowledgements) and inscriptions (photographs, drawings, tables, graphs, charts). The posters provided significant evidence of the teachers' participation and some evidence how teachers increased their participation in their mentor's research agenda.

Changes in Teachers' Beliefs About Nature Of Science

The primary data sources informing teachers' beliefs about the nature of science were the pre/post administrations of the VNOS-C. Responses were coded as informed, developing, or naïve as described by Lederman, Abd-El Khalick, Bell, and Schwartz (2002). The subcategories of NOS codes were constructed in advance of the analysis of the VNOS-C and were derived directly from the list of aspects of NOS included in the seminal work by Lederman et al (2002). Subcategories of NOS codes were constructed from the NOS aspects and were included in Table 6. A matrix was constructed and printed for the coder to use to record their interpretations. A copy of this organizing matrix can be found in Appendix I.

The protocol for coding the pre and post responses to the VNOS-C involved the use of three colors of highlighting pens. Orange was used to code evidence of more informed beliefs about NOS. Blue was used to code evidence of more naïve beliefs.

Red was used to code passages that were significant but not easily categorized as informed or naïve, evidence of developing beliefs. The coder labeled each highlighted passage with the first initial of the subcategory A-L, followed by a forward slash, and

Table 6. NOS Aspects Used for Identifying Informed, Developing, and Naïve Opinions

Symbol	Subcategory
A	Empirical NOS
B	The scientific method
C	General structure and aim of experiments
D	Role of prior expectations in experiments
E	Validity of observationally based theories and disciplines
F	Tentative NOS
G	Difference and relationship between theories and laws
H1	Nature of scientific theories
H2	Functions of scientific theories
H3	Logic of testing scientific theories
I	Creative and imaginative NOS
J	Inference and theoretical entities
K	Theory-laden NOS
L	Social and cultural embeddedness of science

followed with “N” for “more naïve,” “D” for “developing,” or “I” for “more informed.” For example, a passage indicating an informed belief concerning the difference between theories and laws would be coded “G / I.” The coder also made notes in pen in the margin of the teacher responses, providing details as to how they arrived at their categorizations. A sample of a scored matrix was included in Appendix J.

The following are sample passages from the case study participants that are representative of more informed, developing, and more naïve beliefs about specific tenets of the nature of science. Here is an example of a more informed belief on inference and theoretical entities.

> Scientists are generally certain about the structure of the atom, based upon the data gathered to this point. The science textbook, however, is misleading students to believe that there is a recognizable qualitative difference in a

> negative charge as compared to a positive charge. In reality, this is an arbitrary decision and should be listed as such. Still, the model of the atom is more a collection of inferences than a concrete model.

This passage is an example of a developing belief about the difference between theories and laws. “A theory is much more inclusive of phenomena while a law is generally focused on one particular phenomena. Theories are usually much more intricate, while laws are generally simplistic.”

The last passage is an example of a less informed belief about the lack of a single scientific method.

> What makes the category referred to as ‘science’ unique is that it is an attempt to systematize a basis of knowledge derived from a:
>
> - Hypothesis;
> - Observation;
> - Study;
> - Experimentation;
> - Data collection;
> - Analysis; and
> - Following from, with, and through this … a conclusion.
>
> Science attempts through systemization to determine and establish a standard of principles for what is being studied. This makes it unique from religion et philosophy which can be man’s attempt at principles of living, and or dying.

After reviewing all ten questions, the coder skimmed through the organizing matrix, reread segments of the article, and attempted to make decisions about any segments for which the respondents were uncertain. Sometimes one tenet had multiple categories. These were reviewed again. The teachers' responses were then reviewed a second time with the coder looking for specific information about any of the blank categories. After reviewing the coded segments within each aspect, the teachers were determined to hold informed, developing, or naïve opinions of each tenet for which there was evidence the nature of science.

Interrater reliability was determined to be 80% with the assistance of an education professor at the university and six graduate students enrolled in a graduate level course on the nature of science. Disagreements between the author and the other assistants were discussed and modified as needed based on a second review of the original data.

Impact on Teachers' Classrooms

The primary source that informed the third research question was the interview data. QDA Miner was used to assist the coding of the data. Subcategories specific to the impact of the research experience on teachers' classrooms were constructed and modified throughout the initial coding of the interview data. The final list of these subcategories within classrooms can be found in Appendix G.

Interrater reliability was established for the classroom data with the assistance of two experienced secondary science educators, who were trained how to use the established codes in QDA Miner to examine several interviews. An interrater reliability of 90% was established using comparative statistical methods integrated into QDA Miner. Each set of scored codes were compared to the author's and differences in coding negotiated by comparison to the original data.

Construction of the Case Studies

The coded interviews and pre and post assessments using the VNOS-C were triangulated with the poster projects in order to construct six case studies. Each person's coded interview was sorted for each subcategory and printed from QDA Miner to be used in the writing of each case. The poster presentations were compared to the teachers' interviews in order to determine in what phases and to what degree the teachers were able to participate in their mentors' research.

Copies of the organizing matrix and coded responses to the pre and post VNOS-C were placed side by side to identify any changes in teachers' understanding of the aspects of NOS. Other changes in NOS not measured by the VNOS-C but conveyed during the interviews were also included.

Interview data served as the primary data source for constructing the classroom portion of each case. Follow up emails to each of the case study participants filled in gaps as the cases were constructed.

Each case study was sent to the respective teacher, along with a copy of the cross case analysis. This member checking assured the integrity of each case study and allowed for the inclusion of further information that may have been initially missed through the data collection process.

Construction of the Cross-Case Analysis

The cross-case analysis was constructed as informed by Merriam (1998). Following the within-case analysis that led to the construction of the case studies, a coordinated system was developed for the cross-case analysis. The summary sections for a single category were copied from each of the six cases. These were placed side by side and reviewed several times for commonalities.

Emergent themes were identified and a summary table was constructed, as recommended by Miles and Huberman (1984). The emergent themes were recorded in Table 6, page 168. Member checking of the emergent themes was completed by the case study participants as they examined their individual’s case studies.

CHAPTER IV
RESULTS AND DISCUSSION

Organization of the Chapter

The results presented in this chapter are organized into two sets of case studies. Cohort III contributed three case studies, as did Cohort IV. Each case study is divided into six sections: Introduction, Research Assignment, Trajectory of Participation, Influence on Understanding of the Nature of Science, Impact on Classroom Teaching, and Summary.

A collection of the emergent themes from the six case studies immediately follows. Emergent themes are divided into three categories based on their relevance to the three research questions: Participation in Laboratory Research, Nature of Science, and Impact on Classroom Teaching.

The results in this chapter attempt to answer the three research questions of this study:

1. To what degree were the teachers able to increase their participation, thus becoming more valuable to the sensemaking of data and observations and otherwise able to contribute to their mentor's research agenda?
2. To what degree were the teachers learning about the nature of science through participation in scientific research?
3. How did participation in authentic scientific research impact the teachers' classrooms and professional careers?

Case Studies: Cohort III

Myra

Introduction

Myra has taught biology, advanced biology, and anatomy and physiology at the same high school in rural Tennessee for over ten years. Her school has experienced a large increase in enrollment during her tenure. Teaching in rural Tennessee, the overwhelming majority of her students are Caucasian.

Myra completed a Master's degree in Biology years prior to applying to the DOE-ACTS program. Her graduate thesis centered on the structure of the mouths of various species of salamanders found in the Great Smoky Mountains. Field observation and data collection were a large component of her research experience.

Research Assignment

For her first two summers Myra was assigned to the genomics laboratory of the biosciences division. Her ability to contribute to the research was limited. She had poor access to her busy mentor and had to complete extensive training in order to operate the equipment. Another limiting factor was the expense of the equipment and samples examined in the genomics laboratory.

Her final summer in the program she switched to the environmental sciences division. She participated in both field work and laboratory testing. She assisted another member of her cohort and her mentor scientists with a project to understand the effects of cold water on a fish's ability to swim. This project centered on the practical need for the Tennessee Valley Authority (TVA) to limit impingement of fish, the number of fish killed in culverts around power plant water intakes, in the winter. Myra participated in fishing expeditions to collect samples and then observed the effect of cold water temperatures on the fish's ability to swim.

Trajectory of Participation

Myra reported that her biology content knowledge increased greatly during her two years in the genomic laboratory, even though her opportunities to participate in authentic research were severely restricted. Her poster presentation from her second summer was very technical. She shared authorship of the poster with a member of Cohort IV not selected for case study and with two mentoring scientists. Images of both teachers working in the laboratory were included to evidence that they had been involved at some level. Participation in genomics research required her to be trained to use expensive and complicated equipment. Eight weeks for two consecutive summers were not enough time for her to become well-acquainted with the equipment or methods of research design. The poster included what results she and the other teacher obtained. In the interview Myra was frank about her limitations in the genomics lab.

> When I was in the genomics lab, quite frankly there was some equipment I couldn't use. It was very expensive and you had to be trained on it. So the equipment in the (environmental science) lab is much more user-friendly because it's not so technical, if that makes sense… But I did a lot in genomics I'd never done before. It was incredible. I don't want to downplay that.

Myra’s ability to contribute to her mentor’s research increased rapidly throughout her final summer. Her field work and laboratory experiences during her third research summer furthered her aquatic content knowledge. She learned field techniques necessary to collect specimens and conduct experiments on fish. She collected and analyzed data, comparing observations made at multiple temperatures.

> He’s been very willing to include me in different activities. Personally he’s the nicest, most generous person. ‘Whatever you want to do, Myra, just let me know.’ I said, ‘I want to go out on the boat.’ And so I was certified on boat safety so I can go out on a boat. ‘I want to go and do this,’ okay, let me do this for you so you can have that experience. So he’s been very open to providing as many experiences for me as possible. He is not been over my shoulder watching everything I do in my project. He’s sort of told me what it is, did a few practice runs, and then he’s let me be autonomous. He’s not been overbearing or micromanaging.

Her second mentor included Myra in the analysis of data and further direction of the research.

> And when I’ve showed him results and we’ve talked about it, he will suggest ‘okay, let’s try this temperature.’ So he’s helped me modify the original plan. We weren’t going to go below eight degrees. And the fish did fine at eight degrees so we wanted to see maybe six degrees was what affected their swimming ability. He’s allowed me to move out on my own but then felt strongly enough to say

> 'okay let's try this.' Cause I think he's actually going to use this data for his part of his larger project, too.

At the conclusion of summer 2008, Myra was the lead author of one poster presentation and second author for another poster presented by a member of cohort III not selected for case study. Her poster reported the results of her examination of the effects of temperature on the swimming performance of a singular breed of fish. The poster included an introduction, objective, and methods as well as data analysis, results and implications for further research. A large amount of data was reported through photographs, maps, data tables, and graphs. Myra's poster strongly evidenced her participation in all phases of her research project, including the interpretation of results. The second poster reported field work involving culvert sampling. The design of the poster reflected a similar level of sophistication, also including photographs, maps, graphs, and charts.

In spite of her opportunities for increasing her participation Myra was uncomfortable seeing herself as directing research. Her focus and reason for participating in research at the laboratory centered on her students.

> …(conducting her own research) it's not that important to me. What's important to me is to learn as much about current research that's going on here (at the laboratory). I'm all about preparing my students and those students interested in careers in science, I want to let them know what the viable areas are.

Myra recognized that in order for her to grow, she needed to trust the expertise of the research scientists. She positioned herself to learn through observation of the laboratory in action and participation in whatever role the mentor scientist afforded her. The trajectory of her participation was centered on improving her classroom teaching rather than scientific research centered.

> The first thing a mentor asks you is ‘what do you want to get out of this summer?’ But I am happy to be a part of every search, because they’re the specialists and I want to learn what they know. I guess it goes back to my reason for being here and being in this program. And that is to make me a better teacher, not to change careers and go into research.

The majority of the teacher researchers in Myra’s cohort were veteran teachers. She offered the opinion that the teachers of her cohort had no interest in becoming professional researchers, in part because of where they were in their teaching careers. She also noted that some of the teachers in her cohort came to teaching following careers in scientific fields. For these reasons she believed that none of the teachers in her cohort were interested in pursuing science as a career.

> Inter: Have you spoken with anybody for whom this experience has led them to (consider changing careers)? Out of the ACTS group?
>
> Myra: No. You know we have some teachers in my cohort who actually came out of the for-profit sector into teaching. But I think we’re all at the age and the point in our lives that we’re educators now and we’re just looking for ways to make us better educators and prepare our students for what they need.

Myra offered that the mentoring scientist is the key component of the research experience. Her experience with two mentors allowed her to compare and contrast very different mentoring styles. She shared many observations and opinions about what she believed made for a good relationship between the mentor scientist and the teacher researcher. Myra placed accessibility at the top of her list of important qualities of a good mentor. Her relationship with her first mentor was “very open” but very limited because of his other responsibilities. Summer was when he taught a course needed to write grant proposals. The working relationship between Myra and her second mentor was much more interactive. She went on field expeditions and worked beside him conducting various tests in the laboratory. He fostered her pursuit of her original ideas and questions within the context of his ongoing research agenda. She was told that her self-directed efforts would become a part of his larger research report.

> This summer I don’t think there’s anything I’d want to change. And the previous two summers, probably better communication and involvement. I had an awesome mentor that was just doing some really phenomenal research, technical, and I learned a lot from him. He was very open, taught a lot so he was very busy. He just wasn’t available enough. Involved in writing up proposals and so I think my mentor this summer is much more accessible. And maybe that’s the key to this program: having a mentor that is accessible. I think that really is important. Because the mentor is what makes or breaks the experience, don’t you think? …The effectiveness of the program lies not only with the participants, but with the mentors who have agreed to take on those participants. I think it takes a special person.

Myra believed that it was to her benefit to have experienced both laboratory environments. She suggested that the program should consider diversifying the laboratory assignments each summer, and perhaps during the course of each summer.

> I think the more experiences we could have in different labs. I mean, of course it's good to stay in the same lab for the three summers and take care of research. But I also think it's important to see different areas of research, like microbial experience versus aquatics. Looking at life at the level of the organism. I think they're both very important. I appreciate both of those experiences very much. I think diversity is good in that respect.

Myra's participation in scientific research was very limited during her first two years in the genomics laboratory. Her experience during her final summer afforded her the opportunity to contribute meaningfully to her mentor's work while developing her skills in designing, analyzing, and reporting research. Myra gained much more from her experiences working with an accessible mentor, conducting less abstract scientific investigations. She grew frustrated with the glacial pace of her participation in the genomics laboratory. Though she claimed to have enjoyed and appreciated both research environments, her enthusiastic recollection of her final year suggested that she was much more comfortable in a laboratory that gave her hands on experiences and allowed her to participate in multiple aspects of conducting research. Being a veteran teacher vested in her profession Myra had no interest in becoming a professional researcher. She believed that learning more about how to do science was a critical part of her professional development as an educator.

Influence on Understanding of the Nature of Science

Myra’s responses to the VNOS-C during her first summer conducting research suggested that she came into DOE ACTS with a developing understanding of many of the general tenets of the nature of science. Her coded responses provided evidence that Myra held some informed understandings of the empirical nature of science, the general structure and aim of experiments, and the role of inference and theoretical entities.

Myra disagreed with the notion of science as a human construction. She instead perceived scientific truth as an absolute. She explained that “science in its purest form is universal because it explains and understands nature which is not influenced by social and cultural values.” Social and cultural influences impacted only how people perceived and practiced science. “I believe that culture assigns or labels scientific knowledge with particular values. The theory of evolution has been distorted, distended and misunderstood because of cultural overlays.” This statement also reflected a lack of understanding of the tentative nature of scientific theories.

Her post response to the VNOS-C supported the idea that her perception of science as absolute did not change as she worked at the laboratory. She wrote “science supplies explanations and knowledge, culture and society decide how to make use of that knowledge.” She also claimed science and scientific knowledge “are the only valid explanations of natural phenomenon.”

Her beliefs about the roles and differences between laws and theories did change during her tenure of research. Before the program she explicitly stated that “textbooks state that theories can change but laws do not,” using the law and theory of gravity as supporting examples. She did not distinguish between the two in any other way within her responses. Following her final summer she wrote that “scientific theories explain while laws are observations.” She failed to offer any further insight into the tentative nature of theories and laws.

Other responses revealed her ideas about the validity of observationally-based theories and disciplines. Her initial response noted the validity and importance of observation. She claimed that observation often must precede experimentation.

> Scientific knowledge is not random but based on observations. Are all observations derived through experimentation? No, not necessarily. I think of how early naturalists spent timeless hours observing animal behavior in the wild, for example. Their observations would lead to knowledge about basic behavioral patterns. The white tail deer seems most active at dawn and dusk, the male and female red-tail hawk are both involved in child rearing, wolf packs are lead by dominant male and female wolves. These observations are scientific knowledge at the most basic level. Experimentation, whether in the field or the lab, builds on these basic levels to answer questions about the basics.

However, Myra’s beliefs about the design of experimentation became more rigid during her experiences at the laboratory. She saw hypotheses as “specific and measurable.” Her description of experimentation to a belief in experimentation as a structured, straightforward, linear route to a final answer.

> An experiment is a controlled test for a well developed hypothesis. An example might be: ‘A student wants to explain the effect of scary movies on humans and takes the following steps.’
>
> 1. Research the topic. Decide how the effect could be measured. Discover normal parameters of human physiology like heart rate. Discover the effects of fear or stress on the human body.
> 2. Write hypothesis: Scary movies increase heart rate. If the normal heart rate is 70 bpm it will increase by 15% after watching a scary movie. (Hypothesis is specific and measurable)
> 3. Conduct experimental trials to include controls and multiple trials.
> 4. Collect data, analyze, reject or accept hypothesis based on data.
> 5. Write and present findings.

Engaging in scientific research convinced Myra that experimentation was the only path to scientific knowledge. She did acknowledge that reexamination of existing data could lead to novel ideas, but failed to return to observational-based sciences as a source for scientific explanation.

> Novel scientific knowledge which is based on data obtained from empirical evidence requires experimentation. When might experimentation not be required? Perhaps in re-analyzing old data.

Myra found a place for creativity and imagination within the curiosity necessary to design scientific inquiry. She does not explicitly state that they have a role in the interpretive phase.

> The inquiry process begins with curiosity. Curiosity is rooted in creativity and imagination. A scientist must be able to think and create outside the box. The lines of inquiry of Einstein are the perfect example.

Myra expressed belief that science is universal in both her pre and post responses to the VNOS-C. She did grow in her understanding of the difference between laws and theories. She acknowledged that theories do change as a result of reinterpretation of existing data or new data obtained through newly available technologies. Her experiences in the research laboratory narrowed her view of experimentation. Three years working under two different mentors within different branches of biological science left her with the perception of experimental science as a structured, sequential, and singular approach. While she acknowledged observation as important in her pre responses, she only felt that experimentation was important in her post responses. In addition her view of experimentation narrowed to one scientific method. This suggested that research experiences without any further discussion of the nature of science could serve to reinforce and deepen teachers' misconceptions and actually narrow their view of science from what they actually experienced. Context alone is insufficient for change.

Impact on Classroom Teaching

Myra's laboratory experience validated her as a genuine scientist in the eyes of her students. This change in perception translated to a greater respect as a science teacher by her students.

> I think they see me more as a scientist. They definitely see me as someone who knows what they're talking about, most of the time. I let them know if I don't know, but I mention to them that I've done this program in the summer and talk about my project some, but not to the point where I think that will really change their perception.

One very significant change was increased self confidence in her ability to guide and direct student research. Not only was she more confident but she was also more interested in facilitating student research. She decided to integrate more inquiry-based activities into the core science courses she was already teaching.

> I did a project this year, after the gateway tests. I had students work in groups and they had to design and implement an experiment. And I had my doubts about it because it was totally, it wasn't, what's the word I'm looking for, they designed it themselves. It wasn't me telling them what to do. Or it wasn't a cookbook experiment. And they did really well. And I think that this experience has given me the confidence to go more in that direction. Even with fourteen year olds, which is what I mostly teach.

At the beginning of that same year she started a scientific research course at her high school. Four students enrolled in her first course. Myra introduced some of the laboratory techniques she learned in genomics to her students. The genomics techniques she taught helped one student to design their science fair project. The student went on to earn a college scholarship to a state university because of his science fair success. Equipment purchased with funds provided by DOE ACTS allowed her students to conduct the experiments they designed.

> I feel that primarily it's my level of confidence in my abilities has developed most of all and that's something that I've noted that's given me the confidence to direct and facilitate my student's research this past school year. I offered, during my planning period, a research class. I had four research students and I felt well-qualified to direct them in developing a problem and coming up with a question and doing their own background literature search and developing their experimental design.

Part of her agreement with her principal was that she had to teach the course during her planning period. This concession was a sacrifice she lamented. She decided against offering the course in subsequent years. One reason she felt she could not continue to offer the course was the amount of attention and guidance she had to provide the students.

> I envisioned it as being an independent study class with me just checking in on them and setting goals. And they really needed day to day instruction. Otherwise they'd just goof off. And these are the best, these are really good students. But it's just something about high school students. They need direction. Not all students are capable of independent research.

Though she would not again offer the scientific research course, Myra still planned to take her new aquatic field research skills back to her classroom. She believed her students could conduct smaller scale versions of her summer research within the high school setting.

Interviewer: Is this something that you can take back to the classroom?

Myra: Absolutely.

Interviewer: Do you think you're going to build a tank and…

Myra: I have two or three tanks at school. Now I couldn't do a swim setup like I've done here, but we could definitely look at thermal tolerances and behavior of fish at different temperatures.

The greatest change in Myra's teaching was in her confidence in her ability to direct student research. This confidence encouraged her to attempt to integrate authentic research experiences within her approach to science teaching. She added more open-ended inquiry-based experiments into the existing curriculum for freshman biology. She began but was not able to sustain a scientific research course because of a lack of support from her administration. Sacrificing her only planning time made it impossible for her to continue. She underestimated her students' need for her attention. The students' need for attention was not too different from Myra's need for an accessible mentor scientist during her DOE ACTS experience. Her laboratory experiences from her first two years assisted her in guiding the direction of a winning student science fair project. She promised that experiences from her final year would be attempted with her students in the near future.

Summary

In her opinion Myra’s participation in scientific research in two different settings made her a better science teacher. Though unable to increase her participation during her first two summers, she exhibited strong increases in participation when paired with a mentor willing to let her try. Her confidence in her ability to facilitate student research grew tremendously, as did her credibility as a real scientist in the eyes of her students. Myra slowly began to include more opportunities for students to design and conduct their own research investigations within the curriculum of her freshman biology course. She strived to bring her new techniques for experimentation back to her classroom and successfully supported a small group of students in their science fair research.

Her ideas about the nature of science varied little from beginning to end. She was less willing to see observation and inference alone as important contributors to the advancement of scientific knowledge. Her view of experimentation became more narrow and structured. She continued to express the idea that science was universal in nature and that society and culture did not facilitate or frame the invention of new theories and laws. Science was fact. Theories were tentative ideas waiting for new technologies to reveal the absolute truth. Myra’s positivist positionality was strengthened through her research experiences rather than challenged. Immersion in the laboratory was not enough to broaden Myra’s understanding of the nature of science.

Connie

Introduction

Connie was a veteran science teacher of over twenty years. Connie was unique among the case studies because she is the only middle school teacher to complete all three years of the DOE-ACTS program. She was also the only one to have administrative experience, having served as the principal of a private high school for a brief time before deciding she preferred the classroom. Her current teaching assignment involved teaching eighth grade integrated science, including elements of physical science, chemistry, physics, astronomy, geology, and oceanography. Connie taught in a city school not far from where she was born and raised in rural central Kentucky. The population of the city had boomed within the past twenty years in part because of its proximity to the interstate. She has completed a Master’s degree in education.

Prior to going into teaching, Connie spent two years in industry. During her tenure she was assigned to product development, using her undergraduate chemistry skills. This work was her only professional laboratory experience prior to her participation in DOE ACTS.

Research Assignment

Connie was assigned a mentor in the materials science division, who included her in his early work in superhydrophobic materials. She continued with this mentor throughout her entire three years in the program as his research grew from a small project into his primary interest, funded by the military because of its potential for several classified applications.

Trajectory of Participation

As the program of research grew and her experience increased, Connie's role expanded. During her first year Connie performed various tests on different materials, identifying several characteristics of each. In addition to this work, she was asked to assist with the dismantling of a defunct research laboratory. Though her mentor initially was skeptical that the project fit the scope of the program's intentions, Connie considered the experience to be critical to her learning.

> To be honest with you, it's been a really good program for me because I have learned so much cause basically what we did was dismantle a laser lab and you talk about having to learn what you're looking at, what it does, what safety requirements have to be met with it and so I worked a great deal on that and I really enjoyed that project. I think to (mentor) it was kind of a stand in project it was to me, it was great fun for me.

Her second year in the program she assisted her mentor with high school students participating in a summer science enrichment program at the laboratory. She was well suited to work with the population of students, who were from the Appalachian region. The purpose of the program was to provide an introduction to scientific research to students with strong potential but limited experience and resources.

> I was under the impression that these were kids that were like, I guess you'd say the AP (advanced placement) kids. They really aren't. This is not the group that they market to. The kinds of students that they're looking at are the students who probably could be AP kids but because of issues at home, or finances or

> whatever, they're not bright and shining students. But they could be. With as my mother would say, a little kick in the rear, they could be really top notch kids. So I worked with a group of those students and a teacher that came with them, and we developed a high school physics kit that ultimately will become available for high school physics teachers.

In addition to working with samples in the laboratory, Connie also spent part of her second summer collaborating with another member of her cohort to design a curriculum to introduce high school students to superhydrophobic materials. She was the lead author on her poster presentation that summer. The poster defined superhydrophobic materials, explained possible applications, showed the "Moses effect" by which a wafer repelled water, and included a scanning electron microscope image of a superhydrophobic surface. The research summary included two bullets outlining the research going on at the laboratory and two bullets describing the creation and content of the classroom kits.

During Connie's third summer in the program she split time between the laboratory and an opportunity to share her research experience with other teachers. A collaborative Math Science Partnership (MSP) grant between three universities in the state of Tennessee brought three groups of twenty to thirty teachers each to participate in an intensive four day experience touring the laboratory. Connie's mentor gave a forty-five minute presentation before turning the floor over to Connie to share a little about her experience as a teacher working in the laboratory. She described her experience presenting to other teachers.

> I spoke to… three groups of teachers. That was a good experience. I liked that a lot. In the planning of the program we were told that they wanted the teachers to hear a great deal about the mentors' project and then we were to add on how this affected our classrooms. So I did.

Connie's third year tasks in the laboratory consisted mostly of adhesion tests. She laughed as she recounted this work, because "as a chemistry person and a physics person the last time I had my hands on a real microscope was twenty to twenty-five years ago." This experience pushed her to renew lost techniques for using professional microscopes. She pointed out that it was "not the kind you use with eighth grade kids." Her 2008 poster presentation included a short summary paragraph reporting that the adhesion testing revealed promising results. She also included a general description of superhydrophobic materials and a research summary. The limited detail in her final poster can be partially attributed to the fact that the bulk of her mentor's research had been classified by the military.

As reflected by the fact that she kept the same assignment all three years, Connie's relationship with her mentor was very successful. She pointed out that her mentor was born and raised in East Tennessee, which in her opinion made him "very comfortable with people." Characteristics that made him a good mentor included "extreme patience," excellent people skills, and a humble attitude in working with others.

Reflecting on her role at the laboratory, she spoke of the need to become a part of the team. Her expectations for her contribution to her mentor's research were modest. She contributed what she could without feeling a need to pursue her own agenda for research. In doing so, she was afforded the respect of other members of the team and her ideas were encouraged.

> So, as an educator coming in, you have to realize that is your role; to blend in and become part of one of those teams. And what you need to do is take what's there, that team that's there, and work within their ideas. Can you come up with your own ideas? Absolutely! And will these people listen to you? Absolutely! But, no, they're not going to give you free reign to start a new project. Absolutely not.

Connie's experience at the laboratory was a strong example of how important the mentor was to the success of the appointment. Connie pointed to her mentor's willingness and availability to communicate as important ingredients in her increase in participation. She contributed to his work, lamented not being able to contribute more, found time to work on her classroom pedagogy, and became comfortable enough with the research that she was able to present her work not only in posters but also to her peers in a large lecture setting. She even facilitated the shorter research experiences of other students and teachers. She developed new content knowledge, using sophisticated technology to conduct investigations in a field at the cutting edge of science. The confidence her mentor displayed in her abilities and potential helped Connie to know that she could contribute in so many ways and do an excellent job.

Influence on Understanding of the Nature of Science

A comparison of Connie's responses to the VNOS-C from her first year at the laboratory to the school year following her third summer indicated one significant change to her understanding of the twelve aspects of the nature of science. The semi-structured interview with Connie revealed that she came to understanding better how scientists work collaboratively to accomplish tasks. The interview also revealed that she came to know scientists as real people with interests outside of their scientific careers.

Her pre responses regarding the role of creativity and imagination in scientific research limited these to the role they played in the design of experiments. She did not say anything about the need for creativity in the analysis of data. Her post responses indicated some change in her position. She conceded that “scientists have free reign to interpret and develop different theories” about the mass extinction of the dinosaurs and enthusiastically offered that “an effective scientist will use their imagination at all of these steps.”

Other responses to the VNOS-C revealed many positivist views holding fast in her perception of the nature of science. In both her pre and post responses, she described science as a very structured activity.

> Science is a way of acquiring information. It is the way to hypothesize, test, review and revise, re-test, and make conclusions about observations taken from the physical world. Science attempts to compare and contrast situations in controlled environments – ultimately leading to a proposal of possible relationships between the control and test variables.
>
> Science is different from other disciplines of inquiry in that science does not consider the influx of ‘spiritual’ effects upon data statistics. All behavior (data) can be predicted if the underlying physical principles are understood.

Connie described experimentation as an “an attempt to verify or disprove a predicted behavior by manipulating one variable at a time.” She elaborated that experiments were “an attempt to repeat the work of other scientists/participants in order to verify or disprove a prediction.” She reaffirmed the need for experimentation to prove or disprove hypotheses in her post response. “An experiment is an attempt to either prove, disprove, or adjust a hypothesis proposed by a particular field of study.” These descriptions of the nature of experiment were congruent with other positivist beliefs she expressed.

Connie did not mention anything about observation-based sciences or the importance of observation in her description of the scientific process. This omission does not necessarily mean that she believed that observation-based sciences were invalid, but her post response stated that she saw data collection through experimentation as the only way by which scientific knowledge could advance. “The development of scientific knowledge cannot happen without experimentation. Data must be collected... if not, then it is philosophy.” This position left little room to infer that Connie valued observationally-based sciences as an equally important contributor scientific knowledge.

Connie entered the program with a hierarchical understanding of the relationship between theories and laws. Theories were useful but not equal in value or utility to laws. The need for inference in the construction of theory was perceived to be a weakness requiring further experimental verification.

> A scientific theory may or may not be supported by all physical data. Theories recognize the need for retesting and continual verification of the hypothesis. Theories allow for analysis of different circumstances, but ultimately support scientific laws. Different scenarios will ultimately produce supporting data for a scientific law.

Following three summers of research she explicitly expressed the tentativeness of laws as well as theories. She noted that a majority of people did not believe laws required any further verification and then disagreed with the position. She did not suggest a hierarchical relationship by which theory advanced to law.

> (Theories and laws) are both under constant scrutiny for any provable adjustments. I suppose most people assume that the laws will not be disproved, but isn't that what science is all about ultimately?

She proposed that new or changing data was the mechanism by which theories are changed. “Theories change based on data collected. If data is not available, then it is a ‘guess’, not a theory. Data results can always change. It is our job to find out ‘why.’” She did not mention the reinterpretation of existing data as a contributor to the tentativeness of theory.

What Connie came to understand about the nature of science was more related to her observation of other scientists. She came to realize that no one pursued their research agendas alone. Science was the product of the collaborative efforts of a group of scientists. This realization stood in stark contrast to the way scientific discovery was portrayed in textbooks.

> I would have to disagree with (the notion that you’re not given the chance to pursue your own ideas for research). In the sense that you don’t have the time in a nine-month appointment to begin an all new project and to go with an all new concept. What you have to understand is all research is a group effort. Nobody here on this campus works just by themselves. Nobody ever gets ‘oh, I invented,’ or ‘I discovered,’ or ‘I did this all by myself’ because it just doesn’t happen that way.

Another observation Connie shared concerned her personal interaction with other scientists at the laboratory. She initially expected some of the scientists to look down on her because she was a teacher, rather than a professional scientist. Instead, Connie found herself well-respected and encouraged by the scientists with whom she spoke. She found the scientists to be friendly, warm, and engaging, as well as grateful for some inspirational teacher they had in their past.

> Sometimes scientists have a bad reputation of being elitists. They don’t want to talk to anybody. They’re kind of smarter than everybody else. And what I’ve found is that on this campus, I’ve not run into anybody like that. All of these researchers are appreciative of the fact that we’re educators. You know, all of them are like, ‘Well, you’re the reason we’re here. We had a good educator along the way.’ It may have been eighth grade, it may have been tenth grade; but we had a good teacher. And those good teachers are the reason we’re here. And we appreciate that. And they’re all more than willing to talk to you and explain to you and to work with you and it’s been fabulous.

Connie contrasted her experiences at the national laboratory with those she had in industry. She distinguished between the pure sciences agenda of the national laboratory and the applied sciences reinvented in industry.

> The basic difference between a place like (the national laboratory) and an industrial situation (is the type of questions they are pursuing). Because if you're working in industry, you may not necessarily be working with an original idea. You've actually taken somebody else's idea and you may be trying to improve it, you may be trying to change it, you may be making it a little cheaper to do or whatever. But you're not working with that original idea, that basic science. Where at our national lab, and I'm sure it's not just here, I'm sure it's in all our national labs, that's their goal is to find those basic science questions and have those answered.

Connie's understanding of the tenets of the nature of science remained more or less the same despite her three summer immersion in the laboratory environment. Her positivist framework went unchallenged by the tasks she was asked to do. Experimentation was a regimented linear approach to scientific truth, obtained by verification or falsification of hypotheses. She did however recognize the need for creativity and imagination in the processes of science. She also came to understand the difference between theory and law, though it was unclear whether she still perceived a hierarchical relationship between the two. She perceived inference as a stopgap for the absence of knowledge in theory construction rather than recognizing inference as an unavoidable necessity. She recognized the collaborative nature of scientific research but missed the opportunity to connect the collaborative efforts of scientists to the social construction of scientific knowledge. She distinguished between the pure research pursuit of the laboratory and the applied science program of industry.

Impact on Classroom Teaching

The intense energy required to teach demanding students was one reason why so many teachers leave the profession within the first few years. After more than twenty years in the classroom, Connie was very open about the stress teaching places on her. After conducting intense scientific research, forty hours a week for eight weeks, in each of three consecutive summers, one might expect that teacher exhaustion might become a problem. But Connie professed the opposite opinion. The change of pace renewed her energy for teaching.

> Teaching is so demanding and burnout is a real live problem. I don’t care how good a teacher you are and how much you love it. I mean, I teach because I love it. In fact I tell people, why do I teach? Because I want to! If I didn’t want to, I’d go get a real job. <laughs> I teach because I want to. But even with that love of teaching, you get burned out. You just get tired and weary. You need a way to revive. My number one absolute best thing that I’ve pulled out of this program is a revival, a renewal. A ‘this is the reason I’m doing this.’ I come home exhausted every day. At the end of the year I barely know what my name is. But this is the reason why I’m doing this. Because I want to see these kids light up. I want to

> see them learn and those light bulbs to shine and I want to see those connections made.

One tangible impact of the program on Connie's classroom teaching was time she spent her final summer learning how to use classroom technology. She first worked through a short course on Microsoft Excel. Her new knowledge was also useful for her laboratory assignments. She spent several hours learning how to operate a SmartBoard in one of the presentation rooms. Although her classroom is equipped with a SmartBoard, she could not find time during the year to learn and try out many of its features. She claimed that prior to her final summer, all her knowledge about SmartBoard operation came from her students showing her how to do things. Connie returned to her classroom much more comfortable with these technologies and filled with ideas on how to use them in her lessons. She realized that while she was unable to bring sophisticated and expensive equipment to her students, she could use technology to include them in the analysis of data obtained from such equipment. She also felt inspired to become more knowledgeable about SmartBoards in order to serve as a trainer for other science teachers in her school and perhaps surrounding schools.

> Because of the professional development monies that are given us, I will be able to attend a train the trainer conference and training workshop for the SmartBoard. And I would like to become a trainer to the other teachers and the SmartBoard equipment. Because I really feel like that's the next step for our high school classrooms. That's the way. We can't bring scanning electron microscopes into our labs. We can't bring multimillion dollar pieces of equipment

> into our labs. But with the SmartBoard and the SmartBoard technology we can bring the results of those huge pieces of equipment into our lab. We can let the kids see them work and how they work and what they come up with. I think that’s the next big step. Teachers need trainers that are in the trenches with them, not just someone who works for the SmartBoard company and doesn’t have a clue about how it really works in a high school classroom. So I’d like to do that. That’s a project that I’ve set down as a goal for myself.

Connie’s teaching also changed to reflect her new understanding of how a laboratory functioned. Connie shared many observations and insights into the things that made her mentor a successful scientist. These included being knowledgeable about many subjects and being able to communicate and work with people. His ability to work with people was a quality she highly stressed to her students; especially those for whom science comes easily and sometimes underestimated the importance of teamwork within lab groups. She considered these observations a very important thing to pass down to her students.

Yet another observation Connie took back to her students concerned the growing shortage of qualified scientists. When the military began funding the research, they included money to hire research assistants. But because the project involved national security, the assistants were required to be United States citizens. Only two of over two hundred applications were U.S. citizens and neither held the qualifications necessary for the position. Connie took this story back to her classroom with the hope that it might inspire her students to consider going into the sciences and help them understand the many opportunities available to them after finishing college.

Connie also realized that many of her students have no idea what a scientist is or does. Many of her students in rural Appalachia have never met a professional scientist. This absence of experience left Connie to realize that she may be the closest thing to a professional scientist her students will ever know.

> Last year I was talking about my experiences here, something about here. And I had a little kid and he popped up in the back and said, ‘Ms. Connie, you mean you’re a real scientist?’ <laughs from both> Oh, it was so funny and I was like, ‘yeah, I guess so.’ I always thought I was a real scientist. But I thought it was funny how he said that. Because these kids don’t know real scientists. And so to relate to the kids in that sense, yes, I do have that opportunity to do that and I’m going to mount the posters in the classroom and that always leads to questions and then you get to talk about it.

Knowing that she served as a de facto role model for a scientist to her students, she felt it important that she helped them to understand differences between pure and applied science. Having experienced both pursuits in her career she felt well positioned to help her students understand the difference and the significance of both.

> As an educator out with the kids you don’t get to do that (pursue pure research) often. But now I know that’s something I need to explain to the kids. What is the difference between doing basic research and researching an idea that no one

> else has researched? What's the difference between that and working in an industrial setting? That's the way it's important to me now.

Connie's research appointment influenced her teaching in several ways. She left each summer with renewed energy and enthusiasm for science and for teaching. She learned new techniques and knowledge to share with her students. She spent time her final summer familiarizing herself with new classroom technology she would employ in future years. She was inspired to pursue further professional development on the application of SmartBoards in order to better use the technology in her class and to become a resource for other teachers. She used examples from her laboratory experiences to impress upon her students the need for more people to go into science and science related fields. She came to recognize that she was the face of science to her students and perhaps the closest thing to an active scientist they would know in their lives.

Summary

Connie's stable summer research environment allowed her to steadily increase her participation in her mentor's work. She became an expert laboratory technician, contributed her own ideas to the research, assisted in the presentation of the work to audiences of teachers, and facilitated the short term research experiences of other students and teachers from Appalachia. She wrote curriculum while expanding her use of classroom technology. From dismantling a laser laboratory to conducting adhesion tests on superhydrophobic materials, she never complained nor balked at her ability to contribute. The whole time she worked from a position of humility and willingness to do whatever task was set before her.

Her pairing with her mentor was as perfect as could be found in the program. He was available and willing to answer any question she posed without being condescending or verbose. He built her confidence in her abilities and left her wishing she could contribute more. His inclusion of her into his work extended to the presentation of his results. She assisted him with his search for ways to communicate his work to the next generation of young scientists and to their teachers.

She accomplished all her research while holding fast to her positivist beliefs about the tenets of the nature of science. Her belief in scientific method was affirmed. She saw the end result of experimentation as the verification or falsification of hypothesis. While she grew to appreciate the important role that creativity and imagination played in all phases of scientific research, she rejected the importance of inference in the construction of scientific theory. Inference was necessary because of the absence of knowledge, rather than being a necessary consequence of interpretation of observation. She embraced the idea that scientific discovery and invention was the product of many scientists’ efforts while failing to see scientific knowledge as a human construction influenced by theoretical frameworks and human biases. She came to see theory as explanation and law as observation but did not validate both as equal ways of knowing.

Connie renewed her enthusiasm for teaching through her laboratory experiences. She took the time to learn more about educational technologies. She decided to pursue training to become an expert so that she could teach other teachers how to use technology. Unlike many of the other teachers she did not report any increase in her use of inquiry-based teaching methods. Instead she took stories from the laboratory back to her students so they could understand how science was accomplished, the need for new scientists, the importance of having good math skills and problem solving abilities, the need for people skills, and the importance of both pure and applied research. She became the face of science for her students, knowledgeable about facts and about the process of doing science.

Sierra

Introduction

Sierra was an accomplished veteran teacher of twenty-one years in Tennessee. She held two Master's degrees, one in educational research and a second in administration and supervision. Her school for the past several years was an inner-city magnet school she helped found in 1996. She had prior experience assisting with the foundation of another school within the system. The school was a public magnet school with an enrollment of 1300 students and a waiting list of over 300 additional students. The overwhelming majority of the school enrollment was African-American. Sierra spent the majority of her career teaching in predominantly African-American schools. She herself was Caucasian in ethnicity. Sierra's current teaching assignment included honors and advance placement chemistry in addition to a scientific research class. She served as the school's Science Bowl coach.

Sierra had no prior experience in a professional laboratory, though she was married to a professional scientist who held two Ph.D's in psychology. He died sometime before she began her research appointment with DOE ACTS. She spoke of him with great respect and shared about the sacrifices and support she gave him throughout his education and his career. Through him she came to understand much about the nature of science and scientific research.

Research Assignment

Sierra spent all three of her years with the same mentor working on several intense projects in the chemical sciences division. A childhood friend suffered from blindness, an experience that further fueled her enthusiasm for her work. During her second summer in the program she assisted in research concerning a highly experimental technology to implant an array of sixty electrodes into the retinal area of the eye to allow people suffering from retinitis pigmentosa to see again. The device went to clinical trial in over six countries with much success. One implantee had been blind for almost fifty years.

Her third summer in the program she continued to work on a cure for the blind. This project involved the oxygenation of tissues to heal degenerate retinal tissue. Her work specifically involved using electrodes to oxygenate tissue samples. She also worked to design three different vessels to hold a medium in place so that the tissue could properly oxygenate. At her mentor's request, Sierra's posters were not available for inclusion in this study. The research depicted in her posters was proprietary and had not yet been released to the public.

Trajectory of Participation

Sierra spoke about her research projects in passionate terms with great detail. As she described her work she included an extensive understanding of the relevant literature in addition to historical perspectives. This depth of familiarity reflected her contribution to multiple aspects of her mentor's work. It also reflected the investment of time she made in the laboratory. It was not uncommon for her to spend fourteen hours each day in the laboratory. Her attention to detail and thorough understanding of her subject was clear in her description of her assigned research topic.

> There's two diseases in particular that is the focus of the transplant. That is retinitis pigmentosa and macular degeneration. Retinitis pigmentosa can occur when you're young. You hear someone losing, saying 'things are becoming tunnel.' You hear teenagers saying this. That's retinitis pigmentosa. Macular degeneration is usually age-related. And that, too has the same symptomatic things in terms of tunnel vision and vision closing out. There are many young people that suffer from retinitis pigmentosa.
>
> So this covers across the board young people to people who have been blind for almost fifty years, the current generation of implantees. They've only had the implant for nine months, but early results have been very positive. And the bottom line is when you've been blind for decades and all the sudden you can begin to distinguish shapes, light and dark, then this is amazing.

> The current research is that if the retina can be healed and not just degenerate, using an artificial means, because it's actually quite cumbersome, the implant is. It's planted along the retina, the temple path. Then you wear glasses and there's a camera, it's quite elaborate. You have to wear a battery pack, but again, if you've been blind, this is a means to see. However, the oxygenation could be very simplistic.

Sierra was very forward that she was at the laboratory to serve her mentor, not to seek opportunities to follow her own research ideas. Nevertheless it was clear that her ideas and self-direction were held in high esteem by her mentor, who encouraged her to do more than the typical laboratory technician tasks.

> I'm a contributor. I help design. My input, according to my mentor, is extremely important. So I'm not hemmed in if I do have an idea. But I think I offer, I ask more questions than I offer contributions, but (my mentor) asks me and he'll say 'submit a drawing to me' and 'what do you think?'

Her value to the research project led her mentor to find opportunities to continue assisting the project after her tenure with DOE ACTS was completed. He repeatedly expressed disappointment that she would not be returning to his laboratory, telling her "I don't want you to leave."

Sierra's experiences in the laboratory were very structured and organized. She told a story about how she told her mentor that she was 'anal' about her laboratory notebook, to which he replied "You're not anal. You have a love of good clean data."

Her experience at the laboratory reaffirmed her conception of science as a highly organized, sequenced pursuit of new knowledge.

Sierra’s dedication to her research and to her mentor was unmatched by any other participant in the program. She poured herself into all phases of her mentor’s research, from reviewing literature to running repeated experiments to the sensemaking of results. She respectfully contributed her ideas when appropriate and gained the full trust of her mentor in her ability to assist in his work. She brought organizational skills, enthusiasm and unwavering faith to the laboratory every day, fully believing that she would play some small role in bringing sight to the blind and that her mentor would achieve great success in his work. She became as valuable a technician and assistant as a career teacher could hope to become in the course of three summers.

Influence on Understanding of the Nature of Science

Her responses to the VNOS-C revealed no significant changes in her beliefs about the tenets of the nature of science. Her statements indicated she entered the program with an entrenched belief in a positivist philosophy of science. This position did not change during her summers of research and may have been reinforced by her very structured experiences in research. She expressed strong belief in the scientific method and rigid experimentation. “Science attempts through systemization to determine and establish a standard of principles for what is being studied,” and that experiments were “the process of carrying out the above seven (bulleted) steps beginning with a hypotheses to its conclusion.” Her bulleted list included hypothesis, observation, study, experimentation, data collection, analysis, and conclusion.

She agreed that theories change over time. In her example she interchanged laws and theories and hinted at a hierarchical belief that theories are immature laws.

> Of course theories change. While invaluable in the building process toward the systemization of a certain body of knowledge, they are incomplete and have not attained the level known as scientific law or fact as in the shape of the earth. A classic example of theory taken as this law/fact was the earth at the time of Columbus believed to be flat. The laws/facts of science are indisputable, and have been shown time and time again to be the concrete foundations of a body of scientific knowledge through experimentation that, also, finds no contradiction in any other discipline.

She later reinforced this position by claiming that theories are necessary for the revelation of universal laws. The tentative nature of theories was misconstrued to be solely a consequence of ignorance.

> Theories are necessary in the building process. They are ultimately conjecture, albeit educated conjecture. However, the very nature of the investigative scientific process requires study; once something is categorized as theory. While enthusiasm for a theory is deserved, it cannot be assumed to be a law/fact in any way, as we would be misguiding the public as scientists. Here again, the earth is flat while seemingly valid; or the earth being the center of the cosmos while seemingly valid as theory at one point in time was proved to be wrong in the end. Labels are important in teaching, particularly; and we want to never overstate to

> impressionable students a case that a theory is, indeed, a law/fact. Scientific laws/facts are universally indisputable.

Belief in universal fact and truth left little room for creativity and imagination, much less inference, in the development of scientific knowledge. Creativity and imagination served a purpose in hypothesis construction. But to Sierra, imagination served as a bandage until new truths were revealed by future experimentation and new technologies.

> In the actual experimental process the ethics of science leaves no room for ‘imaginative properties of relativity.’ However, the very nature of a hypothesis is an imaginative gifting that has been imparted to an individual/s in some intangible way. However, the development of a theory does leave room for imagination to bring a linkage forth that establishes a connective process until the next phase of discovery is uncovered. It is a commonly accepted developmental and known process that does not violate the fact of painstaking, building block producing, step by step experimentation that lays concrete principles in the hopes of furthering factual findings.

Sierra held firm to her belief in a universal science. She believed that social and cultural influences interfered with the universal truth science had to offer. She expressed the hope that science would eventually overcome the misleading influences of society and culture in uncovering new truths.

> The very fact we are speaking of sixty five million years is enough rationale to say that science reflects both social and cultural values, as well as, being

> universal is true. Science through the ages has reflected the former. History's continuum in the process cannot be denied to be a relevant part of the present as much as it was in the days of Galileo's imprisonment. However, science, as a whole discipline, is teachable. Once greater knowledge is discovered through process et time, scientists usually find that 'sweet spot' of universal acceptance, once proven, of course; and then move on to the next phase of human advancement in the establishment of Scientific Laws.

Sierra's experiences over three summers in a professional laboratory reinforced her positivist ideals. She embraced the scientific method as a way to revealing universal truths. She rejected the idea that scientific knowledge should be socially constructed. She rejected imagination, creativity, and inference as inseparable components of all phases in the process of scientific investigation. To Sierra, the tentativeness of theories was a weakness, caused by lack of knowledge and subsidized by inference, that could eventually be overcome by new technology and experimentation. Absolute truth, embodied in scientific law, was the final result of science.

Impact on Classroom Teaching

Sierra professed that her experiences at the professional laboratory reflected her desire to inspire her students. While she said little about specific changes in pedagogy, Sierra spoke passionately about the scientific research course she was able to begin at her school. Her approach to her research and to her teaching was one of selflessness. She measured her classroom success by the amount of inspiration and confidence she was able to instill in her students.

> I'm here to learn from the greatest minds in the world. I mean, this is our nation's brain trust here. It's the largest lab in the world. Hello! I'm just submitted, totally. I have no conflict about that. I'm here definitely to learn. I'm here to be that vehicle of transmission to my students and cast a vision for them. So I'm very concerned about our nation. Who's going to replace these great minds here and that the baton passes well.

The introduction of a scientific research course held importance not only for her school but also for those across the metropolitan school district in which she worked. Her vision extended beyond the immediate with the hope that her course would open the possibility for other schools to start their own research courses. Unfortunately, a year after completing the program, budget cuts within the system prevented expansion of the course and eventually cost her the opportunity to continue to offer the scientific research course at her school. Nevertheless her successes stood as an example of how a teacher's research experience in a professional laboratory could inspire innovative curricular opportunities for students.

Her mentor's son happened to be a medical doctor with a Ph.D working at a large research institution in her city of residence. This unique position allowed her to continue to participate in scientific research after completing the DOE ACTS program. It also gave her science research students a chance to share in her work thereby affording her students access to professional scientists who could encourage and facilitate their ideas.

> In my scientific research class, they've got full reign. They really do and one of my students' teams presented before five professors in (large U.S. city), one from (Research I institution) and four others from other schools. He was like Jesus in the temple. He was there for two hours and they were questioning him and they were like… so it was very cool.

The scientific research course had a strong impact on one student in particular, who took a painful life experience and turned it into an opportunity to pursue innovation in an existing technology.

> One of my students, he had designed this foam, he wanted to change air bags because they hurt when they (deploy)… he was saying and the kids were telling me they were very hard and you could break a bone. His idea was a foam, and then the foam would disintegrate in a time period, I think eight minutes he told me. We called (industrial company), which is in a suburb of (city), and he spent all morning with the guys who invented the airbag. They picked apart his idea and told him the good parts. And he came back and said, 'I think they're walking away with my idea…'
>
> He got the whole thing of why everything is so protected here at Oak Ridge. And that's why (my mentor) told me to let no one take a photograph of that poster (her poster presentation at the conclusion of the summer). There's a protection mechanism that's got to be there, but at least as a young man he had, for a student to have the liberty, that's changed his life. For (student) to meet with

> those five professors… he got a scholarship out of it, and they're asking him questions.

Sierra entered the program as an exemplary educator who already included inquiry-based investigations and demonstrations in her general science courses. She worked tirelessly to find opportunities for her students to participate in the processes of science. She was convinced that student-centered approaches were necessary to inspire the next generation of scientists and scientifically literate students. Her participation in scientific research was a way for her to network with other scientists, opening new opportunities for her students.

> I think you've got to have, and I think this is where we get so caught up in standards for the letter of the law, so we can check our little boxes, that we lose our spirit, and I think it strangles the normal curriculum. You've got to really invest in your students to do inquiry, or you're missing. If you're just checking boxes off, you're not providing what the nations needs. I think it's a disappointment to kids, because they have this natural, want to blow something up anyway. And I think that's a good thing, because it really does ignite them in science. They always ask me, 'When are we going to blow something up again?' You've got to have a good blow up of something. You know what I'm saying? You've got to have that cycle in there, that 'oh, wow!

Sierra did not incorporate new teaching strategies into her classroom as a result of her research. This absence was in part due to the fact that she already included inquiry-methods in her general science courses. She did negotiate the creation of a scientific research course as a way of providing more space for her students to pursue their own questions. Her tenure at the laboratory introduced her to a network of scientists interested in working with high school students. Her ability to teach increased as a result of her refined laboratory skills and her new contacts to assist students in answering their own scientific questions.

Summary

Sierra's organization, dedication, content knowledge, and ability to work with people allowed her to increase her participation quickly. She immersed herself in the literature and contributed to the development of groundbreaking techniques to bring sight to the blind. She worked tireless hours to accomplish as much as she could for her mentor. She cultivated his confidence through her work ethic and enthusiastic zeal for the project. She became an integral part of the work he did each summer and was asked to continue her efforts in some capacity after she completed her third summer.

Her successful contributions to her mentor's work suggested that her positivist conceptions of science did not interfere with the quality of her work as an experimentalist. She held fast to the scientific method and the hope that science could reveal absolute truths about the universe. She rejected the social construction of scientific knowledge, the role culture played in the construction of knowledge, and role of imagination and creativity in the interpretation of experimental results. The tentativeness of theory was due to the absence of truth. Inference was a weakness of theory that made it less valuable than scientific law. Science was a pursuit of absolute truth, a deterministic result of rigorous experimentation.

The impact of her research experience on her classroom was less dramatic than many because she was already using inquiry-based experiments and facilitating long term scientific investigations with her students. She did use the experience to provide her with the leverage to begin a scientific research course, establishing the model for her metropolitan school district. She also cultivated relationships with the scientists at the laboratory in order to provide more opportunities for her students.

Case Studies: Cohort IV

David

Introduction

David was an experienced teacher of more than ten years. His first teaching position was at a career and technical school. Following his first summer in the ACTS program he took a new position at a traditional school in rural Ohio. His change in jobs was inspired in part by his desire to teach higher level science courses. He taught astronomy, honors biology, and anatomy and physiology the year prior to his second summer in the program. His new school serviced grades seven through twelve with a total enrollment of approximately 550 students. The student population is 97% Caucasian, typical of a rural Ohio school.

David was unique among the case study participants because he had prior experience in a scientific research program for teachers. His first experience was a two year program in Thailand. He was unique among all participants in that he participated in a second research experience for science teachers at the same time he was in DOE ACTS. His interest in astrophysics led him to the Building Exemplary Educational Foundations in Science (BEEFS) program at Ohio University. He was part of a team of four teachers who missed six days throughout the school year in professional development workshops and then traveled to the Green Bank National Radio Astronomy Observatory in West Virginia and the MDM observatory at Kitt Peak in Arizona to participate in spectroscopic research. He was able to arrange a one week delay in the start of his second summer with DOE ACTS so that he could travel to the observatories.

Research Assignment

David was initially paired with Betty, another member of his cohort, to work for the same mentor scientist on algal photosynthetic carbon dioxide fixation, and diatomic hydrogen and oxygen gas production. David was grateful for the content and laboratory skills he learned in this assignment. Unfortunately, the working relationship between the mentor and the teachers deteriorated due to conflicts that David did not feel comfortable sharing about for this project. Neither teacher returned to this mentor for their second year.

David was assigned to the Computational Infrastructure for Nuclear Astrophysics (CINA) group his second and third summers of research. His work involved the computer modeling of elemental synthesis reactions inside supernova explosions. He combed through a suite of numerical codes “used to determine the sensitivity of reaction rates according to various elemental abundances.” The library of codes David worked with was being revised based on experimentation of particle collisions at high energy conducted at the Holifield Radioactive Ion Beam facility. Because David had not earned clearance to that facility, he manipulated data remotely from a location on the laboratory grounds.

During his third summer David continued his work on stellar nucleosynthesis while assisting a team with the development of a web site for stellar explosions explorations. He gathered relevant web sites to link from the site, offered his expertise for the lesson plan designs, and contacted experts on astronomy and on web design for their advice with regard to the site.

Trajectory of Participation

David established himself as a hard worker during his first year in the program. Despite a tenuous relationship with his first mentor, who in addition to being verbally abusive on occasion and demanded that he work hours beyond the typical expectations for teacher participants, he threw himself into his assignment. He waited until two thirds of the summer had passed before he expressed his concerns to the program director.

David's poster from his first year displayed a schematic diagram outlining the process for detecting CO_2 fixation and H_2 and O_2 production. It included highly detailed instructions on how to calibrate the instrument. Two columns of four graphs each reported the data analysis. No conclusions or implications were included.

David requested transfer to an entirely different laboratory site for his second summer. Coming from Ohio to Tennessee each summer, he had no particular ties to Oak Ridge. But David was told that the directors of the national program frowned on transfers between laboratories and so he returned to Oak Ridge with the promise that his next mentor would be much more accommodating.

David did blossom under his second mentor's direction. He described his second mentor as a "wonderful communicator," a "great teacher," and "respectful." He volunteered that these were all traits his first mentor failed to display. Speaking of his second mentor, he said,

> He’s very disciplined. He’s very patient. He’s very respectful of everyone, regardless of whether they’re an undergraduate, graduate, teacher or a colleague. He’s a great communicator. He, unlike many in the world today, his first response to a situation is to listen. He listens very well. Then he comments. Then he listens. So, feedback is important to him and I think I’m actually just going to consider that also his particular technique in some of the things that I do with laboratory instruction when I get back.

David rapidly established himself as a capable assistant to his mentor’s research agenda. He mastered the simulation codes well enough to be offered the opportunity to take a selection of the codes home with him to work on throughout the school year. He even assisted his mentor with presentations to groups of teachers, as Connie did after three years with her mentor.

His second mentor strongly encouraged David to consider his own research interests before he began his final year at the laboratory. David expressed great interest in being included in publishable scientific research. During his interview he expressed disappointment in a broken promise by his first mentor to be included in a paper summarizing his first year’s results. David embraced the opportunity afforded by his mentor to pursue his own interests.

> This year my mentor is talking about me going back to Ohio, using this suite of numerical codes from my home to continue work outside of the ACTS program for his group. So, for me, that’s very exciting and it’s more than enough opportunity for me to pursue additional questions. And, actually, he offers that

> possibility for the future because he says there are other questions here and as he put it, he wants me to look at them and determine which ones I believe that I have an interest in; that would be interesting to pursue. And so, I think it's the best…this is the best.

David was very content to follow his mentor's direction and focus on his primary goal to become a better teacher. When asked about the opportunity the program afforded the teachers to pursue their own ideas for research, he balked at the suggestion that it was a major objective the program.

> I would say if (pursuing your own research ideas) is a really important thing for you to do, you should consider going back to graduate school and finishing your Ph.D. If it isn't and you're just worried about or your concern is primarily just becoming a better teacher and learning more about your subject matter and about the process of science and about the nature of science, then I think it doesn't much matter what topic it is. Although, for this one, I would have to be honest about it, it's something I'm very interested in. Last year's topic was something I wasn't really that much interested in and I learned anyway. And, it was a very...I mean, it's very useful; some of the things I learned last year.

After three summers in the program David was confident in his skills and ability to contribute as a laboratory assistant. While he had no interest in leaving teaching, David certainly wanted to continue working in a laboratory in some capacity. He listed several reasons, including financial benefits and the personal need for further professional development.

> Now that I am finally at home with my assignment, it is time to leave. I have no real idea as to where I will be going next summer or what I will be doing. As a teacher, I need to continue my professional development. I can also always use additional money. I do plan to work somewhere. I have had offers from labs in which I have worked to return again, and I might accept them. But I believe I can learn more if I find another venue in which to pursue professional development in the summer. I wish that Cincinnati was closer to my home, because I have had offers there from professors for part-time jobs as a lab research assistant. But the round trip to and from Cincinnati would eventually kill me

David overcame a bad placement during his first year, striving hard to meet his mentor's unrealistic expectations. He increased his ability to perform many of the tasks required of a professional scientist. His second mentor fostered his desire to do meaningful science and encouraged him to seek out other opportunities. He also expressed a desire to conduct educational research around his idea of using stories to teach science.

Influence on Understanding of the Nature of Science

David entered the program with a very strong understanding of the nature of science. His pre responses to the VNOS-C during his first summer of research revealed many informed opinions in regards to the nature of science, the validity of observationally based theories and disciplines, and the role of creativity and imagination in all phases of scientific research. One exception was his opinion on the difference between law and theory. David's responses revealed an understanding that theories were explanations, but suggested that strong theories are necessary to explain laws. While these responses did not necessarily imply a hierarchical progression from theory to law, they did embody some confusion as to the difference between the two. His post response did not reflect a better understanding of the difference.

> A theory is much more inclusive of phenomena while a law is generally focused on one particular phenomenon. Theories are usually much more intricate, while laws are generally simplistic.

When at the beginning of the program David was asked how scientists characterized the meaning of “a species,” he responded, “Scientists are relatively certain of their characterization of the term ‘species.’ Consanguinity can be used to help determine the label of species (DNA/genes).” David failed to recognize the concept of species as a human construction. David’s response at the end of the program reflected his growth in his understanding of the tentative nature of scientific theories and the subjectivity of definitions.

> I do not think they (scientists) are very certain. Some believe animals that CAN produce fertile offspring but do NOT breed in the wild are different species. I believe that DNA studies will eventually cause us to rethink our concept of what a species is (number of base pairs, etc.)

David also pointed out the dependence of science on inference in understanding the atom. He entered the program with developing ideas about the role of inference.

> The model seems to explain and predict very well so there is a relatively high degree of certainty. Yet since the atom cannot be resolved by optical

> microscopes but only imaged by various spectroscopies, the issue is still open to question.

Two years constructing models of stellar nucleosynthesis helped him improve his understanding of the need for inference. In his post response he acknowledged limitations in scientists' ability to construct models of atoms.

> Scientists are generally certain about the structure of the atom, based upon the data gathered to this point. The science textbook, however, is misleading students to believe that there is a recognizable qualitative difference in a negative charge as compared to a positive charge. In reality, this is an arbitrary decision and should be listed as such. Still, the model of the atom is more a collection of inferences than a concrete model.

David's experiences in a professional laboratory definitely impacted his understanding of the nature of scientific research. He specifically mentioned the role society plays in determining what research is funded and pursued.

> I think I have a better understanding of how policies created or developed by our government affect the path of scientific discovery. If certain initiatives are not funded, certain initiatives may not be pursued. And there's a…there's a waste because I've seen several projects essentially left in the dust where they could have been brought to fruition if funding were available. But, if there's an energy crisis, funding follows the problem and it follows it to the problem and away from some of the other things that you might get also; some valuable patents or inventions or that sort of thing. So, that's one thing that I think I've picked up.

David realized firsthand that the process of doing science was not necessarily a linear progression, but instead was marked by setbacks, delays, and the need to rethink and redo. He shared his experience with setbacks and contrasted it with traditional classroom laboratory experiments. He differentiated between real science, where mistakes and dead ends occurred, and school science, where everything wrapped up in one period and a predetermined conclusion was reached.

> As far as using the computer too, I'll just say that I lost approximately 150 simulations yesterday morning through no fault of my own. It was a discontinuous sort of communication between FORTRAN and this program, this suite of codes. And, I really couldn't understand how it happened but they just simply disappeared. And, I talked to the computer scientist and he said there wasn't anything that he could do. So, I spent about two days rerunning the sim's and I think I have most of them there. That is another point that I want to make about what I learned, with respect to research. I learned that when you're in a classroom, you have an experiment, the experiment ends at the end of the period. You either got it or you didn't get it. That's it. Here, I've gone through, at least three times this year, the first two weeks I ran some simulations based on inaccurate mathematical formulas that someone else gave to me. So, then all that time was essentially wasted. I don't think this is an unusual thing to occur in a lab. I think it's sort of expected.

David's research appointment facilitated growth in his understanding of the nature of science. He possessed a stronger understanding of the role of inference and the social construction of scientific knowledge. He came to understand science as a human endeavor, with unanticipated setbacks, dead ends, and other delays. He did not further his understanding of the difference between theories and laws.

Impact on Classroom Teaching

David provided his students with multiple opportunities to conduct research. This facet of his teaching was established prior to his entry into the program. He even secured funding for students to work in teams as part of a radon outreach project, comparing different methods of detection. He also supported student astronomical research.

> The astronomy outreach project, I already had that at (the first school he taught at), but I'm expecting that to be revitalized and renewed at the (new) high school. Because we have a different setting and the setting is rural and we will not have to compete with mercury vapor lamps. Which in most cases are just at the right wavelength that they mess up common objects which we'll look for; Messier objects. We do have a few high pressure sodium lamps, but they're of a different frequency, a wavelength.

The direct impact of his research experience on his classroom practice was less obvious. The one change in his practice he mentioned was a need to create utility for the skills and techniques he teaches.

> I like to follow the inquiry process. But, at the (technical school), students are sometimes what you might classify as they're atypical or nontraditional. And, they are more comfortable if you tell them what questions it is that they should

> pursue. When I teach at the high school level I now prefer that when I'm going to speak on a particular topic, students review that information. And then, along with that process, I get an idea of learning how to learn. They figure out what they know. They figure out what they need to know. And then, there's that immediate need to go develop it. If you tell students, they say, 'Well, I'm looking at how to do this triple integral. Where am I ever going to use that?' And so, you can tell them that it doesn't mean anything or you can assign them to a particular project or have them choose this particular project. That's the best. And then, they say, 'what are we going to need?' And then the process of figuring out what they need, up pops the triple integral and so, they have to master it. So, you get away from that question of, 'when are we ever going to use this?' or 'why are we learning this now?' It's because you need it now.

As he became more comfortable at his new school, he noticed significant changes in how his students responded to his call for projects.

> My school year is really going well. I think it is the best start to a year that I have ever experienced. Since this my second year, students have now gotten used to the idea that life in science class is never going to be normal again. They eagerly volunteer for projects and additional work, and they believe in themselves. I think I am in a fantasy classroom at the moment.

Like Connie, David realized that he might be the only representation of a scientist his students ever encountered. Participating in research broadened and validated his ability to serve in this capacity.

> Especially in our area, you will never see a scientist. Never. You will rarely see an engineer. If you do, that's a civil engineer. You might see a doctor if you're sick. Otherwise, these people, you don't see. So, people involved in science or math, you don't see. So, they don't understand what it's all about. In these research groups, I have now a number of people including (mentor) that I can have my students access. So, that's what I want them to do.

David integrated scientific research into his general curriculum. He found ways to make the content he taught relevant to his students. He demanded his students make time outside of class to collect and analyze data for long term projects. His ability to foster student research expanded as he networked with many scientists and traveled many places. He became his students' model of how a scientist approaches their work. David's hunger to do research multiplied as a result of his pursuit of relevance in the laboratory.

Summary

David's identity as a scientist grew immensely as a result of his participation in research. He survived the unreasonable expectations of his first mentor to flourish in his second mentor's laboratory. He thrived on the opportunity he was afforded by his mentor in the astrophysics group, taking work home with him at the conclusion of the summer to continue throughout the year. He increased his ability to assist in his mentor's work and was encouraged to choose his assignment from a variety of options. His resilience was a reflection of his interest in learning how to act like a scientist.

His understanding of the nature of science was sharpened and reinforced by his laboratory experiences. He experienced science as a human endeavor with inconvenient starts, stops, and redirections. He came to appreciate the necessity of inference in the construction of theories and scientific definitions. He finished his tenure in line with the generally accepted tenets of NOS, save for the distinct difference between theory and law.

His ability to facilitate student research grew exponentially as a result of his new contacts and new knowledge. He became the lead scientist and transformed his classroom of students into a research group. He pushed all his students to participate in long-term research projects throughout the school year. He refused conventional content-focused curriculum in favor of finding ways to place content in context. David embraced the spirit of his research experience and worked hard to find ways to bring it back to all of his students.

Betty

Introduction

Betty spent her first two professional years working as a research chemist in the Pacific Northwest. After taking a break for several years she moved cross the country and spent a year working for the health department. Boredom with that career path led her to a teaching position at an urban magnet high school in Tennessee with an enrollment close to 800 predominately African American students. After two years of teaching chemistry and physics, she transferred to a predominately Caucasian rural school with an enrollment of 1000 in the same county school system. Her new teaching assignment included chemistry, physical science, and the occasional life science course. She later introduced an environmental chemistry course and an AP Environmental Science course at the school.

The September after finishing her third summer of research, Betty was in a serious automobile accident. When contacted in early October 2009 Betty did not yet feel physically up to sharing more about her final summer of work. She did participate in the member check of her case in late October and shared a few corrections to minor details.

Research Assignment

Betty was assigned to the same mentor as David for her first year in the program, though she worked on a different project from him involving the testing of biochar for nutrient retention for use as a soil amendment to help with carbon sequestration. Her relationship with this mentor soured toward the end of the summer. He became excessively demanding of their time after realizing their internships were ending soon.

She was assigned to a new mentor for her second year at the laboratory. She split her time between a project at a local museum to upgrade exhibits on energy and the preparation of a large technical report to be submitted to the Department of Energy. Her exhibit upgrade project paired her with high school students volunteering at the laboratory for the summer. Her work on the technical report opened her eyes to the bureaucracy involved in funding projects and reporting research results. These tasks did not resemble any other teachers’ placement in the program and did not seem to include any experimental or observational research tasks. Regardless, Betty was satisfied with the tasks assigned to her and embraced them as an opportunity to further her understanding of the business of scientific research and the presentation of informal science to the public.

Trajectory of Participation

Betty entered the program as an established laboratory chemist experienced in design and technician level tasks. Her prior experiences shaped her expectations for what she hoped to gain from the program. She continued to learn new things about the process of doing science.

> I actually came into this with almost three years of actual chemistry lab experience prior to teaching so I had a pretty good idea of what I could include. But I have learned a lot more about, I guess the bureaucracy behind research; that no matter what great idea you may have, there's steps and hurdles that you have to get through to reach those. So I have learned a lot but at the same time some things are the same as what I was expecting.

Her experience in the professional chemistry laboratory involved her in all phases of research, including experimental design and data analysis. Her prior work at the health department did not include her in the processes of experimental design, data interpretation, or sense-making. She worked as a laboratory chemist who followed established, sequential procedures and recorded only the data that was predetermined to be significant. She contrasted her laboratory technician experience with the inclusive nature of her second mentorship.

> I think I've gotten smarter on problem solving steps. My experience before was very cut-and-dry. Follow this procedure. I've gotten a lot more exposure to how to even come up with the ideas that led to what we're working on. So, a lot more experience to the whole scientific method type of idea as opposed to the cut-and-dry "follow this" format.

The problems she experienced with her first mentor could be attributed in part to his knowledge of her prior laboratory experience, which fueled his unrealistic expectations for what she could accomplish for him in such a short time. Her first mentor told her that he had agreed to take her because he needed an experienced assistant to further his work. She noted, "(He) chose me specifically because I had lab experience. As far as the lab experience goes, I don't feel I gained anything last summer." He failed to recognize the difference between an interning apprentice scientist and a teacher assisting in research.

She overcame the poor ending to her first year because of the support she received from the program director and her decision to let go of her frustrations and focus on her future. She confessed that she might have gone to the director earlier if she had better understood the expectations of the program. But as a first year participant in the program she did not know what to expect from her mentor assignment.

> The first four weeks I didn't know what was expected of me and I was so new to the program that I didn't know what to do anyway. It was about six weeks in that my mentor finally figured out that we only had two weeks left and he hadn't gotten everything out of us that he wanted. Things started to get ugly. It was very

> easy going to the ACTS program manager and discussing things with her. Which precipitated me not being back with that mentor, who is actually no longer here (at the laboratory) anyway. It was very easy to talk it over. Had things come to the head before that, I still would have been very comfortable going to her and probably maybe could have changed my assignment had it happened earlier. But it just happened as it happened.

Her mentor’s lack of organization, poor communication, and unreasonable expectations doomed their partnership.

> Communication with my mentor was very much lacking. As far as timelines and expectations and what he, I guess, expected. By the end of the summer I felt more like a cheap hired hand than as a colleague, especially when I was asked to work late nights and weekends because things weren’t progressing to where they should have been because of a lack of organization on his part. That pretty much sums it up. There was a lot of frustration by the end of the summer. But even with that, I did learn quite a bit. I wouldn’t have come back if I didn’t feel it was worthwhile.

She contrasted her first and second summers in terms of her agency to choose the tasks in which she was involved. She believed that

> Last summer I had absolutely no flexibility at all and I don’t really feel like I came away with a whole lot from last summer experience for many various reasons. But this summer, having had the chance to pursue things on my own and decide what may or may not be the most important things to pursue as we’ve done the

> museum ideas. I have learned leaps and bounds beyond what I had expected after last summer's experience. And I have to agree with (friend), you do get a little ownership more, a 'buy in' to it when you have a say in what you're doing.

Her 2007 poster included a long introduction describing their attempt to sequester carbon dioxide from power plant emissions and use it to produce fertilizer, a substantial description of methods, and two sentences summarizing their results. The poster also included a flowchart of the use of biomass to produce electrical energy and the recovery of byproducts from the ash. Photographs illustrated the difference in plant growth with and without the fertilizer. A third figure illustrated the biomass cycle. No conclusions or implications from the research were included in the poster.

When asked whether or not her assignments her second year were satisfying, Betty shared that her new knowledge about energy and various associated technologies made her summer worthwhile.

> Definitely! My content knowledge has increased leaps and bounds. Especially with energy and anything related to energy. It was a very weak area of mine and I've learned a great deal on the technologies that are being developed and just the whole process. I'm a lot more aware and yes, I think so, definitely.

She justified her assignment to the museum exhibit project by categorizing it as the reporting of results. She considered the construction of an exhibit to be a very important part of the process of research science: the reporting of results. Communication of results to persons who are not experts in a particular field was a critical task for purposes of securing funding, furthering the scientific literacy of the general public, and influencing the course of future research.

> Doing the museum research is not something that I ever thought I'd do as a research scientist but that community outreach is a very big part of research. If you can't bring your research to the average person, then your research doesn't go anywhere for a lot of things.

Betty produced a poster in 2008 summarizing her research into hybrid solar lighting. Unfortunately she was unable to attend the poster presentation because she was attending a professional conference and the person designated with displaying her poster failed to do so. She ended up presenting the poster at the 2009 session.

Betty grew in her content knowledge, her ability to communicate results, and her understanding of grant proposals. She left with new perspectives of energy and its associated technologies. She broadened her understanding of the process of scientific research. Betty satisfied the immediate needs of her mentors and happily took what she could from these experiences. But none of the tasks she assisted with matched the typical expectations of an authentic scientific research assignment for teachers.

Influence on Understanding of the Nature of Science

Betty entered the program with a fairly strong understanding of the nature of science. Her explanation of the structure and aim of experiments and recognition of the importance of observation and observation-based sciences were well developed. Her responses after completing the research program revealed a change in her opinions regarding certain tenets of the nature of science.

In both her pre and post responses Betty recognized the importance of observation to the scientific process. She used observation as a way of explaining how experimentation must be flexible enough to be revised. Her first year response rejected a “cookbook” or step by step approach to scientific experimentation. She likewise recognized the validity of observationally-based approaches to science.

> Experiments are not confined to cookbook recipes or measuring quantities of output. They can also be observation-based. No furtherance of scientific knowledge can be made without at least observations of a process or object.

During her interview Betty elaborated further on her beliefs about the absence of a singular scientific method. She compared the need for multiple approaches to science to the need for multiple instructional strategies in her science classroom.

> I’ve found multiple scientific methods out here. Each project has its own little quirks; its own way of doing things. You have to learn to adapt. I think that’s the biggest thing. One of the biggest lessons I’ve taken from this that I hope to take back to the classroom is, you have to be flexible. Things aren’t going to go right, things most often go wrong, and you have to learn to adapt and move on.

When asked to distinguish between laws and theories, Betty differentiated the two by the level of permanence. Laws, though she conceded could change, were much less likely to change. Theories, though well supported by observation and experiment, were more likely to change. She explained the difference in her pre response.

> There is a huge difference. Theories are still very testable, and many have only a finite amount of support. Others have been studied heavily, but have changed so

> much over the years, they could still change more (i.e., atomic theory). The name theory almost begs for you to question. Laws have been tested so much, by all the new technology that has come along, and not changed. The outcomes remain constant. It does not mean that they can't change, just that with the large amounts of evidence supporting it, 'it seems to be true all the time' such as Newton's laws of motion.

Her post response indicated no change in her position on theories and laws. While laws may change, theories are much more likely to "evolve."

> A scientific theory is generally accepted to be true, based on current understandings and technology available. But it does allow for it to evolve... Laws appear to be unchangeable (law of gravity, conservation of mass).

She attributed the tentativeness of theories to the absence of evidence, or the likelihood that advances in technology would reveal new understanding.

> Theories can evolve as the technology and understanding changes. This is very true with atomic theory, as it changed over the course of 300 years to what we have now. It changed as technology got more sophisticated and allowed for research and observations that were unable to be achieved before.

A second post response reinforced her idea that the tentativeness of theory was a consequence of incomplete information.

> A meteor can cause cataclysmic events such as volcanic eruptions to occur. Much of the data would be similar in nature. Because there is limited data, both

> hypotheses are supported. But there is no way to truly experiment or observe that could give a conclusive answer.

One example of how her ideas about the nature of science changed as a result of her participation was her ideas about the empirical as well as the social and cultural embeddedness of the nature of science. Her pre responses to the VNOS-C suggested that she believed science to be socially constructed.

> Both (theories) are true, based upon the individual who is doing the research. There are many scientists doing research on global warming. However, they are doing it for different reasons. Some are doing it for the social/cultural impact. How it will affect us, our way of life, etc. While there are others that are studying it because it’s there to study. Has this happened before? How? Why? What’s really causing it? It is the researcher and their motives that truly determine which of these they represent.

Her post response suggested that she believed science to be universal. Inference, culture, and scientists beliefs and biases were rejected as having any role in the process of science.

> Science is man's way to understand and explain the everyday things around him, from how he breathes, to why the sky is blue, to what makes glass different than steel. It is based on continuous study, observation and measurement, not on impressions, opinions or beliefs.

Her post response limited the social influence on the construction of scientific knowledge to the decision of what work was funded.

> Those things we choose to study, and how they are studied, as well as starting hypotheses, are often influenced by the needs or wants of society. Cell phones are one of those things that derived from a science fiction idea (culture), and the studies and science were done to construct the reality. Stem cells, and whether or not they can even be studied, is greatly influenced in its funding by politics.

One significant change in Betty's understanding of the nature of science was her observation of how much energy the research scientists spent securing funding and meeting the requirements of the funding agencies. She noted that the actual time her mentor spent working in the laboratory was much less than she expected.

> The fact that they don't spend all their time in a lab actually hands-on is one of the biggest things to me. How much time they actually spend trying to get the funding to do what they want. It takes up a lot more time than the actual performance of the project itself. I think that was my biggest change in thought. Just how much time is not spent in the lab, but how much time is spent persuading people to give you money to do the project. And then the accountability of that, I've really seen with writing this technical report. You have to account for all of your time, all of your material. Why you did what you did and how it came about.

Betty's experiences at the laboratory reinforced many of her conceptions of science while moving her to a more universal position regarding the nature of scientific truth. Her experiences did not impact her beliefs about the difference between scientific theory and law. She was less willing at the end to embrace the idea that science was a product of human inference and creativity. Though she believed science to be universal and uninfluenced by society or culture, she noted that funding agencies consume much of the scientist’s time and dictate much of what they may accomplish.

Impact on Classroom Teaching

Like many of the other participants included in this case study, Betty was very focused on improving her teaching. She had completed three years in the classroom prior to beginning the program. Her pedagogy was open to experimentation and new ideas. Participation in research reinforced her formative ideas about how to involve students in authentic science.

> My primary reason was to improve my teaching. I’m still considered a relative ‘newby’ to teaching with only five years. I know that things have to change in science education in general and I’m willing to hear everything out there and see what’s out there. I’m not locked into this is how I was taught and so this is how it must be done. I’m willing to do what’s best for my personality and using my background, because I know what it can be like.

Inquiry-based experiments were a major empasis of Betty’s coursework in education. When she entered the classroom she reverted back to more didactic, content-focused approach. Her experiences in the laboratory forced her to reconsider this approach. She boldly began including more student-designed experiments in her curriculum and was pleased to find her students were more interested and engaged in their assignments.

> I started trying a lot more experiments that the kids are designing themselves this last year, and those are the ones I found them the most engaged in. And I think that’s why I’ve had a much better summer. I’m able to pursue what my interests were to an extent. When you’re interested in something you tend to be more engaged and more excited. And I saw the same things with my students this past year. And it just reinforced for me this next coming year.

The inclusion of student-designed experiments into her science curriculum increased her students’ enthusiasm for doing science. Betty was pleased that her students were discovering that science did not always have a straightforward method or solution.

> …make sure that I include even more of that if possible. More of letting them try things out. And it’s okay if you don’t know what the answer is. They need to learn that science can be messy and that it doesn’t always go as you want. That’s what it’s about; figuring things out.

Betty’s unconventional research assignment was able to be extended to her students in a very tangible manner. Her research on energy and related technologies for the museum exhibit became a project for her AP Environmental Science students.

> They (students) actually will be helping me, since we’ve made this into a two year upgrade of the museum. Especially as we have to find funding. My AP students are going to be working towards that. A real world application of things.

Betty’s assignment at the laboratory impacted her teaching by inspiring her to include inquiry-based experiences in her regular classroom. She did not start a course specific to research but instead changed the way she taught all of her courses. Though her mentor's research was not something she could replicate at her school, she modeled her approach to classroom research on her experiences at the laboratory. Her students' interest in research and science in general grew as a result. She reinvented her approach to teaching at an early and critical point in her career.

Summary

During her first year Betty suffered through the same unrealistic expectations imposed by the mentor she shared with David. Like David, she too returned for a second and third summer with a different mentor. Unlike David, she split time between two mentors working on two unique projects that provided her with little opportunity to work in a laboratory. She was content with her new assignments, taking advantage of the opportunity to learn about energy technologies in order to develop a new museum exhibit and coming to know much about the bureaucracy surrounding the funding for research. She rationalized her experience by emphasizing the importance of scientists' learning how to communicate scientific results to the general public and to the people funding their work. Her experiences during her second and third years provided an opportunity to learn more about the administrative side of science rather than the doing of science.

Her understanding of the tenets of the nature of science regressed as a result of her research appointment. She moved toward more universal ideals concerning the nature of scientific truth. She disregarded the importance of inference to the construction of theory and failed to recognize the importance of creativity and imagination to the interpretation of scientific results. She maintained misunderstandings about the difference between theory and law. Though denying the influence of society and culture in determining scientific truth, she recognized that market forces and funding agencies controlled what scientific investigations were pursued.

Betty did transform her curriculum as a result of her experiences in professional development and immersion in the culture of the laboratory. She included opportunities for her students to design their own experiments and investigations into her general curriculum. She included her students in her museum exhibit background research. Having limited experience in the classroom, Betty knew that she needed to explore new methods of teaching. She found what she was looking for in the DOE ACTS program.

Joseph

Introduction

Joseph entered the DOE ACTS program having taught Algebra II and Foundations of Algebra for three years at a suburban high school within five miles of the national laboratory. During his time at the laboratory Joseph convinced his school administration to let him begin teaching an AP Computer Science course. In addition to his teaching assignment, Joseph also served as an assistant football coach for the varsity team and later head coach of the freshman team.

Joseph was unique among the members of the case studies and the program participants as a whole because he was the only mathematics teacher to participate in the first four cohorts. Prior to entering the program he had no experience working in a professional laboratory. He began his teaching career after finishing his Bachelor’s degree in math education. He started work on a Master’s degree in mathematics after completing his third summer at the laboratory.

Research Assignment

Joseph spent his first two years working for the same mentor in computational science. His project involved writing programs in JMOL to build three dimensional, visual representations of molecules that could be rotated and scaled to various orientations or sizes. Visualization of models in a Java based environment was a project he could take back to his classroom on a lesser scale.

His final summer at the laboratory he was assigned to the Center for Nanophase Material Sciences to work on a project involving high temperature superconductive materials. He worked with scientists to find patterns across a variety of high temperature superconductive materials in order to better understand their properties. He particularly enjoyed this work because of the relevance of electricity to his students and the multiple applications he was familiarized with through his work.

Trajectory of Participation

Joseph grew in confidence and stature throughout his experience at the laboratory. When he entered the program he questioned how he could contribute to his mentor’s research. His mentor’s high expectations and belief in his potential encouraged him to work hard and excel. Joseph quickly discovered he was more than capable of learning quickly and performing his responsibilities at a high level.

> I actually ended up doing more than what I expected doing. You know, I was kind of expecting to be at a lower level and them putting me at a lower level, and

> there wasn't; you know, they had high expectations for me and like I said, there were things I could do, there was things I couldn't do, but it was a learning process.

Joseph's increased participation was reflected in his first two posters. His 2007 poster chronicled his work on a project to network multiple computer programmers. It included a large diagram of the computer network, screen shots of the network login and program coding software, and a few other images related to the project. One sentence in large bold font described the project. None of the typical components of a scientific poster presentation, except the title, were included.

His 2008 poster was much more detailed. It included a full description of the applications of the software, specific features, and a screen shot of code. He also included the model he had spent the summer constructing and images of models created by others. It was much better organized than his first poster, though it did not include labeled sections as one would expect on a scientific poster.

One factor that contributed to Joseph's successful appointment was his first mentor's willingness to give him many options. Being able to choose a project he was interested in made him more comfortable and willing to try new challenges. It allowed him to find an activity that had some utility for his future teaching.

> Well, at the beginning of each summer, like I said, I've had a different type of project and my mentor sat down with me, and he's put out, you know, we've talked about what I'm doing in the classroom, what we're doing, and he's saying, "Here's this we're working on", and there's…you know, they have a list of things

> that they are all working on at the same time. So it was kind of, “Here’s what we are working on, here’s how it works, would this be helpful, you know, would this be helpful to you”. So I kind of got to pick my project.

Joseph appreciated the confidence his first mentor put in his ability to work independently. He admitted that he preferred to be left alone to some degree and worked best when not constantly being watched. When Joseph had a question, he asked. But he did not require the constant attention of a mentor, which might have otherwise smothered him.

> One thing I really liked about him is he didn’t stay on top of me, you know, making sure I had this done, making sure I had this. It was, you know, “Here’s work, when you have questions, when you get through, come to me”, so I was kind of free to do that.

Autonomy was for the most part a very positive part of Joseph’s experience with his first mentor. Joseph did confess that at times that his mentor’s busy schedule left him without someone to consult. During these times Joseph networked with other scientists in the building or with other members of his cohort.

> One thing that is tough, you know that I found out during the summer, is that there are many days that they are not there. You know, there were many days that I would come in and need help or something like that and there was no one there, you know, they were either busy doing something else. So it was kind of tough because there were certain days that I really couldn’t do anything.

Joseph’s need for autonomy did not mean that he wanted to be completely independent in the laboratory. He held no aspirations to pursue his own research questions, though he enjoyed having some say in the project to which he was assigned. He perceived himself as someone who could contribute in some small way to the larger needs of others.

> If it was just me working on something, you know, given a project and saying, ‘Hey. Do this,’ I don’t think I’d have been too helpful, but it was kind of, ‘Hey, this is what this group of people are doing, can you put some input on to this,’ so at that point, yes.

Joseph was surprised throughout his research experience at the level of participation he was able to achieve and the contributions he was able to make to his projects. He proved to himself that he could work independently or collaboratively as the situation dictated. He completed his years of research with new confidence in his ability to learn and to adapt to the responsibilities of any task set before him. This confidence manifested itself in his decision to pursue an advanced degree in his content field of mathematics. His example strongly reinforced the notion that teachers were given the resources and opportunity to increase their participation each summer.

Influence on Understanding of the Nature of Science

Joseph was trained in mathematics and computer science, not the natural sciences. His responses to the VNOS-C before entering the program revealed many opinions that reflected his lack of experience and everyday familiarity with a particular branch of science. This positionality made him an excellent subject for understanding how the performance of scientific tasks under the guidance of a mentor impacted a person's constructs of the nature of science.

Joseph's opinions of science were strongly positivist when he began his appointment and failed to shift very much during his three summers. He professed that science was universal, factual, and concrete. Science was not the product of inference or imagination, nor was it socially or culturally constructed.

> I believe basic science is universal. As we get more and more complicated, scientists work on ideas that are important to a culture and many times scientists are influenced by who is paying the bill.

Joseph limited the role of creativity and imagination to the design of scientific experiments. Creativity was not a part of how data and observations were interpreted. This position was in line with his idea that science is about finding facts.

> I think it is important for scientists to use creativity in the pre-planning stage to foresee problems that may arise in the future. If a problem is already defined well, I don't think creativity and imagination are needed as much.

In his pre responses to the VNOS-C, Joseph described theories as immature laws lacking full factual support. He described the transition of theories to laws as how theories "evolve." He proposed that the evolution of theories depended on the uncovering of new facts that supported or rejected the hypothesis. He voiced his idea that theories evolve in his post response. The comments below were made on his pretest.

> A theory is based on facts but is not proven. Evolution is a theory; we have facts to support it but not to prove it. Law is something that is proven, such that water is made up of hydrogen and oxygen.

Little to no change is found in Joseph’s perceptions of the nature of science as measured by the VNOS-C questionnaire. What Joseph learned about the nature of science was best understood by examining his interview responses. Joseph observed the importance of collaboration within scientific research and the recognized the need for scientists to be skilled in a range of different areas of expertise.

> One thing I figured out too, is that all the people, they had a mixture of degrees. These were, they were either physicists that, you know, came and learned computer science, or these are really computer science people that are having to learn the science aspect of it. So there is not really one person in there that had one specific job; you know, they had to know it all.

Without a background in science to draw from, Joseph entered the program with very positivist positions on the basic tenets of NOS. His research assignments had little impact on his beliefs. He pronounced scientific truth to be universal. He believed that scientific proof was the desired goal of experimentation. He recognized that theories changed, but attributed this to an evolutionary process by which theory ascends to law. He recognized that collaboration is necessary for the pursuit of scientific knowledge but failed to express any sentiment that knowledge is socially constructed. Though he was immersed in the context of science, he failed to reflect on its nature in any transformative manner.

Impact on Classroom Teaching

Joseph grew in his understanding of computer science during the two summers. He wrote programs to construct three dimensional molecular models. His new skills and methods translated to his classroom in multiple ways. The most immediate impact was his introduction of an AP Computer Science course to his schedule.

> My AP Computer Science class wasn't started until after I did this. I've set up this when I do zero period, before school, and you know I've got twelve students in it, and they've volunteered to come in before school to take the class. So that's been my biggest undertaking since starting this.

Joseph knew how to program before he began his work at the laboratory. He gained new insights into how to program as a result of his experience at the laboratory, and he passed these on to his students.

> It's not so much the specifics, no, but the overall picture, yes. I mean, because there are just different ways the programming is used, and not so much that, but their techniques of programming is what I really brought back into the classroom.

Another immediate impact on Joseph's teaching was a new emphasis on group collaboration. Having observed how scientists work together and share responsibilities within projects at the laboratory, Joseph was convicted of its importance in his classroom.

> Group collaboration, you know I wasn't big into that until now, and we actually set up some, a system, like a subversion system so that people can check out, you know, say there's a major project. They can check it out, add their input to it, and

> put it back into this big suppository-type thing so that way you know who did what; everyone can see who did what and everyone kind of has free-will on it. So, I've actually kind of set that up in my classroom.

Joseph introduced group work into his course despite the difficulties it created for him in grading and planning. He challenged himself to try new ideas for grading and supervision.

> That was the biggest thing that I brought back into my classroom, is being able to collaborate. Because, a lot of teachers…it's hard to do, because it's hard to grade, and it's hard to get kids together. Using the computer program that we had before, I can document, everything can be documented. I can see when people aren't pulling their part because everything they do has been documented. It's saved, there's a timeline, you know, all of that. Any changes they make. So it's easy when my kids are working on a project; say I have them in a group. They can pull it out, they can, I can see who did what work. They can see who did what work. You know, and it brings up a lot of conversation amongst them. You know, it helps them leadership-wise, to say who's going to do what and work towards a common goal.

Yet another impact on Joseph's classroom was a new confidence in the relevance for the content and methods he was sharing with his students. The great respect the laboratory holds in his community gave him new authority with the students. He could say, with confidence, that his methods were how it was done by the professionals.

> One thing I’ve learned what research really is, and like I said, it’s the mind, the process of it that I really didn’t know before, and it’s not so much teaching facts now, it’s just like, ‘Hey, you know, this can be used for this’ and I can tell my kids in my computer science classes, ‘This is the way it’s done. And you’re not going to work on the projects that we worked on at the lab, you know, it’s going to be much smaller scale, but it can be developed.’

As a football coach teaching lower track mathematics courses, the level of respect afforded to Joseph by the students at his school was not always very high. Working at the laboratory not only furthered Joseph’s confidence, but it added credibility to him in the eyes of his students.

> In one of the conversations we were having the other day, you know, and I was talking about some of the things that I was able to do and one student said, ‘I thought you were a football coach,’ and I was like, ‘I am a football coach, but that doesn’t mean I’m a dummy!’

Students were not the only people who altered their perception of Joseph. In order to convince the school system to allow him to teach the AP Computer Science course, Joseph leaned heavily on the support of his mentor and other scientists at the laboratory. He surveyed several scientists to generate an informed opinion of what high school students needed to know about computer science before going to university. Joseph did not believe the course would have been approved without the support of the laboratory.

> When I started the zero class, it wasn't just starting it up, I had to go talk to a lot of people. I pushed it at the school board, I pushed it at the administration level, I had to push for this to happen and you know, the pushing is not just trying to talk them into it, I had to write things up. I had to do that, so I think the leadership part of that, you know, I think they had a little more respect.
>
> I was able from that, as saying, "Hey, this is things that are going on at the lab. Here are things that they want to see. Here are things that they want to see in a high school". And I got that from them. I went and questioned them, and was like, "What do you want? What do you think a high school should be doing?" So, you know, I had people back me up in that.

Joseph's experiences in the laboratory impacted the courses that he taught, his approach to group work, and bolstered his credibility with his students and administrators. It inspired him to pursue further professional development in mathematics. The fall term following his third summer of research Joseph started coursework toward the completion of a Master's degree in mathematics. The confidence and vision he developed while participating in laboratory research forever altered the trajectory of his career.

Summary

As the only mathematics teacher in the program, Joseph had to build his confidence in his ability to participate in scientific research. He surprised himself throughout his first two years, coming to realize that he was much more capable of contributing to his mentors' work than he initially perceived. The encouragement of his mentor was especially important to this process, as was the autonomy he needed in order to avoid feeling pressured or controlled. He proved to himself that he was capable of learning and adapting to the demands of research and increased his participation each summer. This new confidence coupled with his desire for further professional development inspired him to spend his evenings pursuing his Master's degree in mathematics.

His ideas about the nature of science reflected his inexperience in science. Unfortunately participation in research alone was not enough to change his convictions. He continued to believe science was concerned with the revelation of absolute truths about the universe while harboring misconceptions about theories, laws, and scientific method. His observation of science as the collaborative effort of many scientists did not translate into an understanding of scientific knowledge as a socially constructed entity.

As a relatively young teacher, Joseph had much to gain from his appointment. He was finally appreciated for his talents. Being associated with the laboratory reinvented his identity from "football coach" to respected and knowledgeable mathematics and computer science teacher. His relationships with scientists at the laboratory helped him to push for the creation of an AP Computer Science course at his school. He applied his observations of the group nature of scientific research to transform his approach to student assignments. Rather than focusing solely on the achievement of individuals, he placed emphasis on the ability to work successfully with others in teams. He reinvented his approach to teaching as a direct result of his reflection on what students needed to be successful in a work environment such as that of the national laboratory.

Cross Case Analysis

Introduction

The cross case analysis was organized to inform each of the three major research questions. The first section reported on the degree to which teachers were able to increase their participation during their internship in an authentic scientific research laboratory. The second section reported changes and lack of changes in the teachers' understanding of the nature of science. The third section reported on the impact of the scientific research experience on the teachers' classrooms. Table 7 summarizes the emergent themes from the case studies.

Legitimate Peripheral Participation in the Laboratory

Five themes related to the legitimate peripheral participation of the teachers emerged from the coded interview data. Participation in multiple summers of research allowed the teachers to increase their participation in the laboratory. Over time the teachers became competent in their assigned subject, including both factual knowledge and specific methods for research. As they became comfortable within the context of their laboratory, the teachers sharpened their ability to form and share ideas about the direction and interpretation of the research. The teachers then pursued their own ideas within the framework of their mentors' research agendas.

Table 7. List of Emergent Themes from the Case Studies

Legitimate Peripheral Participation in the Laboratory

- Teachers increased their participation over the course of the three research summers.
- Teachers increased their content knowledge.
- Teachers developed insights into how to design and conduct research and were able to pursue some of their own ideas.
- Patient and available mentors who were good communicators were better received by the teachers.
- Teachers assisted their mentors with the communication of their research to the public.

Understanding of the Nature of Science

- Teachers constructed an understanding of the community of practice: how the research laboratory operated.
- Working in the laboratory reinforced teachers' positivist ideas about NOS.
- Teachers embraced science as a highly organized and structured pursuit that required experimentation.
- The majority of the teachers expressed belief in science as the pursuit of universal and absolute truth. The tentative NOS were a consequence of limited knowledge to eventually be replaced by fact.
- None of the teachers provided more informed definitions of theory or law, and those who believed in a hierarchical relationship between the two did not change their opinions.
- Teachers recognized the importance of creativity and imagination in the design of experimentation but not necessarily in the interpretation of results.
- Teachers believed inference was a means to compensate for a lack of knowledge and the reason theories were inferior to laws.
- The scientists' collaborative approach to research did not sway the teachers' opinions of the social and cultural embeddedness of scientific knowledge.

Table 7 (Continued)

Impact on Classroom Teaching

- Teachers employed new teaching strategies based on their experiences in the laboratory.
- Teachers developed confidence in their ability to facilitate inquiry-based activities.
- Some teachers developed the confidence and skills to offer long-term scientific research courses at their school.
- Some teachers developed the confidence and skills to offer advanced placement courses at their school.
- Teachers renewed their enthusiasm for teaching and for science.
- Teachers were afforded more respect from their students.

Increased Participation

Each of the teachers in the program was able to increase their contributions to their mentor’s research agenda over the course of their appointments. Examples of increased participation included Myra’s contributions to the direction of her research on the effects of temperature on the velocity of fish, Connie’s training to use new more sophisticated equipment, Sierra’s development of techniques for oxygenating tissue samples in the laboratory, David’s increased responsibilities constructing computer simulations, Betty’s extensive research of energy and related technologies, and Joseph’s ability to adapt to new responsibilities and tasks provided by his mentor.

Science Content

Increased content knowledge referred to both factual knowledge in a given subject and the ability to operate and conduct scientific tasks. Myra expanded her factual knowledge of fish while learning techniques to capture specimens and conduct velocity and fatigue tests. Connie learned factual knowledge about superhydrophobic materials and how to make them while learning how to conduct adhesion tests using sophisticated microscopes. Sierra extensively reviewed literature related to her research topic and learned about new technologies that had the potential to bring sight to the blind. David learned how to simulate stellar nucleosynthesis using computer modeling. Betty increased her factual knowledge of energy and energy technologies. Joseph learned how to use software to construct models of molecules and became acquainted with superconductive materials and their future applications in power distribution.

Pursuit of Their Own Ideas

Two of the six teachers were able to contribute in small ways to their research design. Myra suggested new testing parameters and was encouraged by her mentor to pursue it. Sierra was given latitude to develop a component critical to experimentation on tissue samples.

Quality of Relationships with Mentor Scientists

Four of the six teachers switched mentors at some part of their research experience. Myra and Joseph switched mentors after their second summer to pursue different research topics. David and Betty switched mentors after their first summer because they had a poor relationship with their mentor. Teachers who reported poor relationships with their mentors cited unrealistic expectations, poor availability, poor organization, and the mentor’s inability to communicate effectively. Teachers who reported good relationships with their mentors cited willingness to listen, patience, availability, and communication as qualities they respected and believed contributed to their ability to serve in the laboratory.

Communication of Research

The mentor scientists utilized the skills of their interning teachers in the communication of their research results to the public. Connie assisted in the development of a high school curriculum unit on superhydrophobic materials, facilitated the research experiences of teachers and students from another summer program, and assisted her mentor with presentations to large groups of teachers in a summer program touring the laboratory. David assisted his mentor in presenting his research on stellar nucleosynthesis to large groups of teachers touring the laboratory during the summer. Betty researched energy and energy technologies and constructed an exhibit for display at a local science museum.

Understanding of the Nature of Science

The teachers were immersed in the context of scientific research. They became familiar with the everyday operations of the laboratory. However a comparison of teachers’ pre and post responses to the VNOS-C showed that their ideas about the tenets of the nature of science remained mostly unchanged.

How the Research Laboratory Operates

All of the teachers learned something new about how scientific laboratories operated. For two of the teachers, this experience was their first opportunity to experience what a scientist actually does; to see things through a scientist's perspective. Teachers noted the collaborative nature of scientific research, the pursuit of pure science, the need to secure funding and to report results, and the unavoidable potential for setbacks, delays, and dead ends.

Collaborative Nature of Research

Several teachers commented that they had no idea how important collaboration was to the research process. None of the placements reinforced the stereotype of the lone scientific genius. Teachers reflected on the importance of teamwork, the division of labor, and the sharing of ideas. Several teachers offered that the collaborations they had observed influenced their teaching, changing their approach to group assignments.

Structure and Aim of Experiment

A comparison of teachers' pre and post responses to the VNOS-C indicated that they believed experimentation was the only way to advance scientific knowledge. One teacher who mentioned naturalist observation extensively in her pre response failed to make any room for observational science in her post response. Five of the six teachers' responses concerning the scientific method revealed a stronger acceptance of science as a linear and highly structured pursuit, reducible to step by step procedures. The lone dissenter referred to his personal setbacks and dead ends as representative of the true nature of scientific exploration.

Tentative NOS

Several of the teachers mentioned their belief in science as universal truth. Yet teachers spoke of scientific theories as tentative. They explained this potential paradox as the tentativeness of scientific results and the limitations of current technology and means of experimentation. As new technology was discovered and new techniques applied, scientists got closer to the truth. The tentativeness of theory and law was a product of incomplete knowledge. This position had implications for the role of inference in theory construction. Only Myra mentioned the potential for reinterpretation of data as a possible reason for theory to be revised.

Theories and Laws

Several of the teachers proclaimed a hierarchical relationship between theory and law, explaining that because theories were based on inference, a consequence of incomplete knowledge, they were subservient to the more proven scientific law. Definitions of theory and law were provided by the teachers in their pre and post responses to the VNOS-C. Comparison of these did not provide evidence of any improvement in teachers' understanding of the difference between the two.

Creative and Imaginative NOS

Teachers limited creativity and imagination to the conception and design of experiments. Creativity and imagination were actually included less in the post responses than the pre responses to the VNOS-C. Two of the teachers specifically mentioned Einstein in their responses but failed to elaborate on how he used creativity and imagination in his pursuit of science.

Inference

Teachers were asked to report the confidence of the scientific community in the current model of atomic structure. Teacher responses indicated that their faith in the current model of the structure of the atom was high because of the direct evidence scientists obtained through experimentation and the use of new instruments. Only David, who had spent two summers building computer simulations of stellar nucleosynthesis, talked about the atomic model's dependence on inference and interpretation of data. When the teachers were asked about the certainty of scientists' definition of species, several mentioned the potential for DNA analysis to revolutionize the process of determining species. New technology and methods had the potential to bring scientists closer to the absolute definition of species. The need to depend on inference to construct scientific theories was considered a weakness of theories and contributed to their belief in a hierarchical structure between theory and law.

Social and Cultural Embeddedness

The teachers' overwhelming belief in science as universal was evidence that they believed social and cultural influences had no place in the pursuit of scientific knowledge. Science was objective and free of bias. Knowledge was absolute and not socially constructed.

Impact on Classrooms

The self-reported impact of the DOE ACTS experience on their classroom teaching is a product of the scientific research they conducted and the professional development in which they participated. Teachers included new teaching strategies in their classrooms, developed confidence in their ability to direct open-ended student research, introduced new research and advanced placement courses, renewed their enthusiasm for teaching, and earned new respect from their students.

Classroom Teaching Strategies

The education professional development reinforced the teachers’ prior experience with inquiry methods of teaching. Myra and Betty found ways to include open-ended inquiry-based activities in their curriculum. Betty claimed to have moved from didactic to inquiry-based instructional methods. David increased the number of scientific investigations his students participated in outside of the regular school day through the assignment of projects. Joseph began to emphasize collaboration between students working on computer programming projects.

Teacher Confidence

Several teachers remarked that their participation in scientific research and increased content knowledge contributed to increased confidence in facilitating student research. Teachers reported the inclusion of inquiry-based methods in their core courses and the creation of courses dedicated to long-term scientific inquiry.

Created Long-Term Scientific Research Courses

Both Myra and Sierra created scientific research courses at their respective schools. They used their contacts from the laboratory to support their students’ ideas for research and used funds provided by the DOE ACTS program to purchase equipment and supplies for their students to use in conducting research. Though limited resources at both schools prohibited the courses from being sustained, the teachers did all they could to make it happen, with encouragement from the scientists from the national laboratory.

Introduced Advanced Placement Courses

Both Betty and David started advanced placement (AP) courses at their respective schools. Betty started an AP Environmental Science course while David started an AP Computer Science course. Scientists at the laboratory were instrumental in convincing David’s school to offer the course. Both courses continued to be offered each school year as a permanent part of the school curriculum.

Enthusiasm

Connie shared how her enthusiasm for teaching was renewed through their research experiences. She claimed her summer experiences helped her to combat burn out. Other teachers, including Sierra and Betty, reported increased enthusiasm for science and scientific research.

Respect from Students

All of the teachers acknowledged that their students’ opinions changed in some way as they participated in multiple summers of research. Connie and David specifically mentioned how their students viewed them as genuine scientists. Teaching in rural areas, Connie and David confessed that they might be the closest thing to a professional scientist their students may ever encounter. Joseph shared how his students’ came to view him as more knowledgeable of content and were less likely to condescendingly refer to him as just a football coach.

CHAPTER V

CONCLUSIONS

Introduction

This work is an attempt to use six dimensions of scientific research experiences for teachers to reflect upon the significance of participation in multiple summers of authentic scientific research. Special attention is given to how these experiences transformed their understanding of what it meant to be a scientist and their classroom teaching. The six dimensions were embedded within the three research questions directing this study. The trajectory of participation of the teacher, content knowledge development, and mentor relationships were integrated into the first research question. The nature of science was examined through the second research question. Teacher confidence and classroom practice were investigated through the third research question. The following conclusions were organized and presented in order of the original six dimensions of SRE.

Conclusions

Trajectory of Participation

Legitimate Peripheral Participation Served as a Fruitful Lens for Examining SRE

This study is one of the first attempts to employ LPP as a theoretical framework for examination of teachers' experience in a scientific research laboratory. This lens allowed the researcher to determine whether or not the teachers were able to learn over the course of three summers of scientific research.

Learning was defined by Lave and Wenger (1991) as increased participation in a community of practice. The community of practice was defined to be the research laboratory, though the trajectory of participation did not direct the teacher to become a full time research scientist. No teacher could be expected to design and pursue their own course of research. They were assigned mentors specifically for the purpose of serving as apprentice scientists within the context of their mentors' work.

The trajectory of participation was an achievable goal for the teachers to accomplish and reflected the true spirit of the objectives of the program. This trajectory was measurable through methods of qualitative case study. Posters and interviews provided enough information to determine whether or not the teachers increased their participation and thus were learning.

Teachers Were Able to Increase Their Participation

Evidence strongly showed that five of the six teachers examined through case study were able to increase their participation. These five met their mentor's expectations and were given increased responsibility for the direction of their contributions. Myra became involved in the analysis of data and direction of future investigations. Sierra designed and tested prototypes of components. David invented and tested new simulation codes.

The posters presented by these five teachers illustrated their participation in data collection, data analysis, and construction of conclusions. Interviews with the teachers illuminated how the teachers increased their participation within their assigned laboratory or eventually sought out other mentors who would include them in more significant roles.

Only one of the six teachers (Betty) did not participate in original scientific research during her final two years. She instead focused on peripheral but important scientific tasks: the writing of a summative report for a grant funding agency and researching literature on energy and energy technology to construct a museum exhibit. Though she did not increase her participation within an original scientific investigation, the synthesis of existing knowledge is an important element of scientific research.

Content Knowledge Development

Teachers Increased Content Knowledge

The diverse nature of the teachers' experiences made construction of an instrument to measure pre/post gains in teachers' factual content knowledge impossible. All of the teachers reported increased content knowledge. During their interviews they described specialized content knowledge related to their work in intimate detail. The posters reflected the teachers' mastery of specialized content knowledge through use of scientific jargon and sophisticated methods of experimentation and data transformation.

The relevance of the teachers' new knowledge to the content knowledge necessary to be a successful teacher may be debated, but in most cases the teachers were able to relate their new content knowledge to some section of the subjects they were currently teaching.

Mentor Relationships

Qualities of Mentor-Teacher Relationships

Drayton and Falk (2006) studied mentor-teacher relationships and identified five dimensions for success. One dimension regarded the negotiation of roles between the scientist and the teacher. Drayton and Falk found that no single set of responses to the dimensions suggested success or failure in the matching of mentoring scientists with teachers. Rather, it was pairing scientists and teachers who held similar expectations that made all the difference. The level of interest the mentor had in including the teacher in the activities of the laboratory was very important. So was the mentor’s capability to respect the teacher as a career professional with special knowledge and insights into the teaching of science. While teachers wanted to contribute as much as they could to their mentor’s research, they were limited in the time, expertise, and the investment they could make in the research project. Mentors overly interested in the end results of the teachers’ work were more likely to be disappointed with the teachers’ accomplishments.

This study reinforces Drayton and Falk’s realization that the mentor and teacher had to be in agreement in order for the experience to be successful. Mentors who expected too much or too little (Myra, David, Betty) from the teacher eventually lost the teacher to another mentor. Success was possible for both accessible mentors (Connie, Myra) and less accessible mentors (Joseph, David).

In general, good candidates for mentor scientists included those who were willing to spend quality time directing and encouraging the teachers. They had to be willing to explain the science in terms that the teacher could understand and answer any questions the teacher had in a respectful tone. They knew when to leave the teacher alone and let them work, evidencing their trust in the teachers' abilities as a scientist. They also knew when the teachers needed more time and guidance in pursuing their research.

Nature of Science

Immersion in Context is Not Enough to Transform NOS Views

Schwartz, Lederman, and Crawford (2004) determined that doing science was not enough to develop teachers' conceptions of NOS. They suggested that the doing of science could serve as a context for teachers' reflection on NOS. Change was the result of explicit instruction in NOS that included multiple opportunities to reflect on what they were doing in the laboratory.

In this study, the single professional development day when the tenets of NOS were explicitly introduced compounded by a lack of further NOS discussion resulted in no noticeable change in the teachers' overarching beliefs about NOS. Participation in scientific research without explicit instruction was not enough to elicit change in teachers' beliefs. Instead, teachers' experiences seemed to reinforce their existing philosophies of science.

One might propose that the teachers' relationship with their mentoring scientist should impact their beliefs about NOS. Glasson and Bentley (2000) examined the beliefs of six scientists and engineers engaged in cutting edge research. They found that these scientists' beliefs about NOS included heavily empirical beliefs, rigid ideas about experimental design, and firm belief in the objectivity of science as a value free endeavor. Their study shows that the successful practice of science does not require one to believe in the subjectivity of knowledge construction or even acknowledgement of the absence of a preferred scientific method. If the practice of science does not require such beliefs, it is very possible that the mentoring scientists who worked with the teachers in this study may not have held such beliefs either. It is unlikely that the mentoring scientists directly challenged teacher's philosophies of science in the course of scientific investigation.

Laboratory Assignments Entrenched Teachers' Prior Positivist Views of NOS

Five of the teachers' initial responses to the VNOS-C reflected positivist views. Teachers described science as the process of uncovering universal truths. The need for inference was considered to be a weakness of scientific theory. That weakness was why theories were tentative in nature and why theories were considered to be lesser than immutable laws. Only through revelation of truth through concrete observations provided by advanced technologies and inspired new experimental approaches could theories advance to laws.

Participation in research without reflection on the tenets of NOS using the research experience as a context served to reinforce the teachers' positivist ideas. They became more entrenched in their beliefs about a scientific method and the limited role of creativity and imagination to the construction of experimentation. Scientific knowledge was not socially constructed and influenced by cultural beliefs. Society may have dictated what research was funded, but social philosophies played no role in the discovery of scientific fact. This lack of change could be attributed to the exclusion of the teachers from some phases of the research, especially the interpretation of data. None of the elements of the teachers' research experience were enough on their own to sway the teachers' NOS beliefs.

Laboratory Assignments Reinforced Teachers' Prior Post-Positivist Views of NOS

David entered the program with more informed ideas about the nature of science. A comparison of his initial and final responses to the VNOS-C revealed that he left the program with more informed views of the role of inference in theory construction and the lack of a direct scientific method. Both of these changes could be attributed to specific challenges he faced during his research appointment. The very nature of the stellar nucleosynthesis research to which he was assigned relied on inference of processes internal to the star based on observations of the stellar exterior (size, temperature, composition). He constructed computer simulations to infer what might happen to atoms colliding with one another at high velocities, high pressures, and high temperatures. It would have been a greater surprise if he had not mentioned inference. The furthering of his understanding of scientific method was inferred from his experience losing data. He spoke at length about how classroom science was different than research science, differentiating the two by expected outcomes. Classroom science had to come out right in a set period of time, but research science took detours, backtracked, and hit dead ends.

Since David began with more informed views, he was able to reflect on his personal research experiences to build upon that framework. A comparison of David to the other teachers who reinforced their positivist views suggested that research experiences tended to reinforce whatever ideas about the nature of science a teacher initially held. The positionality of the teacher served as the lens through which they observed the research laboratory and its activities. Without the reflective intervention and direct instruction prescribed by Schwartz, Lederman, and Crawford (2002) the teachers were unable to change their position.

Observation of Collaboration Failed To Convince Teachers of the Social Nature of the Construction of Knowledge

Teachers reported that prior to their research appointments they had no idea that scientific research depended so heavily on the collaboration of many scientists who had diverse areas of expertise. Despite observing their mentors at work with other scientists, teachers held on to their prior beliefs about the nature of scientific knowledge construction. Scientific knowledge was considered to be the end result of a deductive scientific method with the capability to uncover and prove universal truths.

Years of poorly written textbooks may have reinforced the teachers’ positivist ideals. Perhaps the teachers’ failed to make this connection because they had no opportunity to reflect upon and reconsider what the scientists were doing. The teachers may have failed to observe the scientists in the act of collaboratively interpreting the results. Regardless of the reasons, the teachers’ inability to conclude that knowledge was socially constructed was a result of firmly entrenched philosophies not being challenged or reconsidered.

Teacher Confidence

Teachers Improved Their Confidence in Facilitating Inquiry

Hemler (1997), Langford and Huntley (1999), Melear et al. (2000), and Drayton and Falk (2006) reported that participation in scientific research experiences had the potential to increase a teachers' self-confidence. This study reported increases in teachers overall confidence, their confidence in directing student research, and their confidence in using inquiry-based instructional methods.

This study proposes that more attention must be paid to teachers' confidence in order to promote teaching through inquiry. Two of the six teachers (Connie and Betty) in this study had some limited professional experience in science prior to DOE ACTS. Two others (Myra and David) had prior experience in scientific research. But only two of the teachers (David and Sierra) claimed to make use of inquiry on a regular basis in their classroom. Though the number of teachers in this case study was small, both of the teachers who reported significant increases in the role of inquiry in their teaching (Myra and Betty) reflected on the confidence they gained in their ability to direct student inquiry as a result of their experiences in DOE ACTS.

Confidence in teaching through inquiry is the product of fruitful and meaningful laboratory experiences, healthy relationships with practicing scientists, recognition of the significance of inquiry methods to the future of science, and familiarity with various approaches to successful inquiry teaching. DOE ACTS provided these elements to the teachers in this study through the laboratory assignments and educational professional development. Though Myra and Betty had participated in science in significant ways prior to the program, each needed the influence of mentoring scientists and educational professional development to charge them to try inquiry.

Teachers Transformed Their Identities

Hemler (1997), Langford and Huntley (1999), and Drayton and Falk (2006) also found evidence that participation in research experiences for teachers increased teachers' status in the eyes of their students. During their interviews Connie, David, and Joseph reported similar changes in students' perceptions of their teachers. Connie and David, both teachers from rural areas, were perceived as real scientists by their students. Joseph transformed his identity from football coach to knowledgeable computer scientist.

Too often teachers are believed to have elected to go into teaching because they were incapable of performing in their field of study. The NSES (1996) stressed the need for prospective teachers to demonstrate their ability to participate in the professional activities of their field before becoming classroom teachers. Research experiences such as those of the teachers examined in this study have the potential to illuminate the tremendous talents and skills of those who chose education as a profession and refute old and narrow perceptions.

Teachers' Rejuvenation and Renewal

Westerlund, Garcia, Koke, and Mason (2002) reported that the teachers in their study reported that participation in research left them feeling rejuvenated. Connie reported a similar renewal and credited it with helping her to face down burnout.

Participation in research transformed her identity and gave her opportunity to practice the profession for which she initially trained.

Classroom Practice

Increased Knowledge Leads to Inquiry Teaching

Raphael, Tobias, and Greenberg (1999), Westerlund et al. (2002), and Drayton and Falk (2006) claimed that increased content knowledge acquired through participation in scientific research experiences resulted in teachers including more inquiry-based instructional methods in their curricula. This study provided additional evidence that teachers increased their use of inquiry-based instructional methods. The study was unable to determine whether the increases were the result of the educational professional development, the participation in scientific research, or more likely a combination of both influences.

Participation in Research Positioned Teachers to Influence School Curriculum

The influence the five secondary educators had on the curriculua of their schools was unmatched by any previous investigation into SREs. Two teachers proposed and taught semester long scientific research courses. Two others were able to convince their schools to let them begin teaching advanced placement courses in their field of expertise. One teacher changed schools in order to teach more advanced science courses and embed student-designed research in the curriculum.

Association with the laboratory legitimized the efforts of these teachers to introduce new courses. Joseph explicitly stated that the support from the scientists convinced the school that the course needed to be offered and his personal affiliation with the laboratory legitimized his students' confidence in his qualifications to teach advanced placement level courses. Betty may have introduced the AP Environmental Science course even if she had not been involved with the laboratory. Sierra and Myra would most likely have never been successful convincing their school administrators to allow them to introduce semester long research courses at their schools.

Being able to draw on their laboratory expertise only reinforced the teachers' success in teaching the courses. David, Sierra, and Myra were able to bring elements from their research topics back for their students to build upon. Increases in content knowledge helped Joseph and Betty to be more successful teaching their respective AP curricula.

Recommendations for Designing SREs for Teachers

One natural consequence of coming to understand the teachers' experiences is to inform the design of future research experiences for teachers. How does one construct a successful research experience for teachers? Is the time and effort invested in three summers of professional development an effective professional development experience for teachers? The results of this study were compared to those found previously in the literature. Langley and Huntley (1999), Westerlund et al. (2002) and Drayton and Falk (2006) each offered recommendations and guiding principles for the design of future scientific research experiences for teachers (SREs). The scope of their recommendations was limited to one year research assignments. The following recommendations were constructed to inform the design of multiple stage research programs based on this examination of the DOE ACTS program.

Selection of Teachers

The selection of teachers invited to participate in SREs was the sum of multiple considerations unique to each research facility. Multiple summer appointments required a large time commitment on the part of the laboratory and the participant. None of the participants in the program had less than three years of classroom teaching experience at the time of their selection. Several teachers had more than twenty years experience. The full measure of the ways teachers benefited from their research experiences revealed some common experiences and some unique to the needs, years in the classroom, prior laboratory experiences, and direct experiences in the laboratory during the course of their appointments. Replication of all the possible benefits to participation in research may be unattainable through case study methods. Nevertheless this study provided some insights into the qualities of successful teacher researchers.

If the objective of the SRE was to influence how teachers teach, then newer teachers to the profession benefited more than the veteran teachers. Newer teachers were still in the formative years in their approach to teaching and responded well to the push for more inquiry-based activities in their classrooms. This is not to say that veteran teachers did not benefit from participation in SREs. Veteran teachers were more likely to already have included inquiry-based methods in their classrooms. Being more established in their school communities, veteran teachers tended to invest their experiences in the creation of courses dedicated to scientific research.

Interest in learning more about scientific research was a key factor to the success of the participants. All of the teachers included in the case studies were very interested in learning from and assisting their mentors. Regardless of the teachers' prior laboratory experience none of the teachers believed their ability to direct or interpret research was equal to or more capable than that of their mentor. None of the teachers openly concerned themselves with proving to themselves or to others that they were capable scientists in their own right.

Maintain a Scientific Notebook

The educational professional development part of the program required the first year teachers to maintain a scientific notebook. The purposes behind keeping the notebook were many. Professional scientists keep meticulous notebooks of their own, so why should teachers not do so? Recent trends in pedagogy encouraged teachers to require their students to keep scientific notebooks and to record the details of their experimental work. Keeping a laboratory notebook modeled this pedagogical approach for the teachers. The notebook served as a place for teachers to chronicle what and why they were doing specific tasks in the laboratory. The notebook provided evidence that the teacher was conducting experiments and assisting with the analysis and interpretation of results.

However, the teachers did not continue to keep a formal notebook during their second and third summers. This natural account of the teachers' experiences as a scientist was lost. Teachers were possibly recording data in their mentor scientists' notebooks instead of keeping one of their own. It is possible that data collection and data analysis was completed electronically thus eliminating the utility of a formal notebook.

Scientific notebooks have the potential to show the richness of the teachers' experiences in the laboratory and the growth in their content knowledge. Some type of notebook and the pedagogical discussion of them may be an important component of scientific research experiences.

Reflect on Philosophy

Teaching NOS through classroom investigations was a significant recommendation of the NSES. Without specific reflection on the tenets of NOS, participation in research did not change teachers' beliefs. SREs should include some opportunity for teachers to share their experiences with their peers, discuss common difficulties and problems, and consider their beliefs about of the nature of science within the context of their collective experiences. Short readings about NOS should be considered to place previous scientific discoveries in historical context and to illustrate different philosophical positions.

The discussion should be led by an expert on NOS, not necessarily a scientist. Expertise in scientific content did not always translate to expertise in the philosophy of science. Many successful scientists continue to practice while holding alternative or antiquated conceptions of the nature of science.

Continue the Emphasis on Pedagogy

The teachers in the program benefited greatly from the professional development in data-driven decision making and persuasive presentation. Less clear was how change in classroom pedagogy continued to be facilitated. The program handbook listed the refinement of the teachers' education modules as a very important component of the program. Professional development in data-driven decision making was relevant to the teacher's active analysis of the student data they collected during their first year teaching the education module. It was less clear how the professional development on persuasive presentation related to the refinement education modules.

Teachers reported increases in the number of inquiry-based activities they included in their classrooms. Part of their impetus for inquiry was derived from their observation of the skills their students needed to have in order to become novice researchers. Further opportunities to consider pedagogy would have facilitated the teachers in assisting one another in the refinement their modules. There was some anecdotal evidence that this occurred informally on a very limited scale as friendships developed between members of a cohort. An organized effort might better facilitate this process.

Offer Flexibility to Experience Multiple Laboratories

Myra suggested that the program should consider placing teachers in multiple laboratory assignments, broadening the teachers' experiences. Myra, Betty, David, and Joseph all switched mentors at some point in their appointments. Each was still able to contribute to the research of the laboratories in significant ways. Each appreciated having had both experiences. Teachers should be given the option to continue the research to which they were initially assigned or to work for another mentor on another project.

Because the purpose of the research appointment was for teachers to become more informed, diversifying the laboratory assignment could inform the teachers of the different fields, methods, and approaches to scientific research. The program must consider the amount of time required for a teacher participating in a given laboratory to become able to contribute to the research in meaningful ways. Eight weeks was enough for Myra to contribute to the field assignments while two years were not enough for her to contribute fully in the genomics lab. Careful consideration of prior knowledge and experiences on the part of the teacher may be important in making decisions regarding multiple laboratory experiences.

There were benefits for teachers who finished with the same mentor and for those who changed mentors. The two teachers who worked with the same mentor all three years became very valuable to their mentor’s work. One was able to lead other teachers and students participating in research. The other was trusted enough to design and select components for a prototype.

One possible solution to the need for experiences in multiple laboratories would be more opportunity for the teachers to share about the work in which they were participating. This interaction would allow teachers to learn about the other laboratories through the eyes of the other teachers. The poster session concluding each summer was one example of teacher interaction, but multiple opportunities to share and reflect on their laboratory experiences are necessary for the teachers to come to rich knowledge of how other laboratories operate.

One of the strengths of the DOE ACTS program was the teachers' flexibility to reconsider or continue their appointments. Such latitude was possible because of the long duration of the teachers' research appointments. The rich and diverse opportunities the large laboratory was able to provide the teachers contributed greatly to their overall experience.

Further Questions for Investigation

Teachers' Classrooms

This study reported increases in the number of inquiry-based and student directed activities the teachers included in their courses. Information regarding the scope and quality of these opportunities was self-reported by the teachers themselves. There were limited examples in the literature of direct examination of teachers in their classrooms before or after their participation in research experiences. The scope and quality of the changes in teachers' approach to inquiry teaching could be further investigated.

The factors in a research experience that led teachers to increase the number of inquiry-based investigations in their teaching are not clear from this study and could be further identified. Were the increases observed a result of the educational professional development, teachers' observations of science in action, or the combination of the two? Understanding what motivated the teachers to include more inquiry in their curriculum would allow future SREs to design more effective programs.

Changing NOS Through Research and Reflection

One important finding of this study was that participation in SREs reinforced whatever philosophical lens the teachers used to view the processes of science. Introduction to the tenets of NOS without further discussion or reflection had no effect on the teachers' beliefs. Teachers who subscribed to a positivist worldview became more entrenched in their positivist beliefs. The one teacher who entered with more post-positivist beliefs left more convinced of his views.

NOS change as a result of scientific research experiences were investigated by Bell, Blair, Lederman and Crawford (2003) and Schwartz, Lederman, and Crawford (2004). Bell et al. focused on the experiences of high school students receiving no organized instruction on NOS. Schwartz et al. focused on preservice teachers placed with scientists at the host university and concurrently enrolled in a course dedicated to NOS instruction.

This study is one of the first examinations of the impact of multiple summers of scientific research experiences on teachers' beliefs about NOS. The subjects of this study received little direct instruction on the general tenets of NOS. This study reinforced the claim of Schwartz et al. that contextual experience in the laboratory in the absence of direct instruction yielded no change. Future research must consider why long term participation in a scientific laboratory had so little an effect on teachers' beliefs.

Discussion

Three summers of service as apprentice scientists in a research laboratory is a significant investment of time and money in the professional development of a relatively small number of teachers. It is important to consider the value of such programs to the laboratory and the mentoring scientists, as well as to the teachers.

There are many reasons for a large research laboratory to open its doors to teachers in the first place. The program handbook describes the program's official objectives in its welcome and introduction:

> The DOE is proud to support science, mathematics, and technology teachers and hopes that this experience will help you to grow in your content knowledge, to become an agent for positive change in your school district, and to serve as a better ambassador for the science community to the next generation of scientists, researchers, engineers, and mathematicians.

Hosting such a program is an important contribution to the laboratory's public relations. Professional laboratories depend upon the financial support from grant agencies. In the special case of a national laboratory sponsored by the Department of Energy, research is primarily funded by the federal government through various agencies. Opening the laboratory to teachers is another way to promote the research activities of the facility to the surrounding communities and the general public. The teachers were trained to serve as "ambassadors" of the laboratory's work to their classes of students. These ambassadors were expected to inspire the next generation of scientists while at the same time informing the next generation of voters within a democratic society.

For the mentor scientists, participation in the program was a chance to reach outside the laboratory and have a direct influence on the future course of science education. The scientists took the opportunity to learn from the teachers about the real conditions of schools. They encouraged teachers with stories about “that one special teacher” who had inspired them to pursue science. The scientists utilized the teachers’ expertise in communication. Two teachers from cohort III collaborated with each other to design a curriculum to introduce their mentor’s work to others. Other teachers assisted their mentors with presentations to groups of teachers, broadening the initial program’s expectations for the teachers to serve as ambassadors. Some of the teachers assisted their mentors with the facilitation of other groups of teachers and students who visited the laboratory during the summer for one to two week short term research experiences.

The mentor scientists benefited by having competent technicians capable of learning and returning for subsequent summers of work. The teachers served in several of the capacities of a graduate student intern, though the intensity of the teachers’ involvement in the research may not have been as extensive. The teachers brought the added value of life experience, an excellent work ethic tested by years of very demanding and intense activities within their schools. Because the Department of Energy funded the teachers’ salaries and other expenses, these highly capable additional technicians were added at no cost to the mentor’s research budget.

This statement does not mean to imply that the mentors made no investment of resources in the teachers. As the teachers quickly realized, their mentor's time was a precious commodity split between writing grant proposals, reviewing literature, summarizing and reporting results, writing formal papers, presenting research at conferences, networking with other scientists, and of course actually conducting experiments in the laboratory. The scientists contributed some funds from their budgets to support the teachers' travel to conferences and their equipment needs.

The most successful mentors were those well-matched to their teachers' expectations. Accessible mentor scientists were treasured and adulated by the teachers. These mentors were willing to listen to the teachers' questions and respond in a way that did not patronize or overwhelm them. These mentors were not exasperated by having to answer many questions, having to repeat themselves on occasion, and/or offer alternate explanations. The time the mentor scientists invested was a significant contribution to the teachers' professional development of their content knowledge, increased ability to perform and interpret tasks in the laboratory, and to understand what it meant to be a research scientist.

The benefits of scientific research experiences to the teaching of science have been shown by multiple studies, including this one. It is clear that teachers' classroom practices did change. The way these teachers were viewed in their schools also changed. Multiple summers of research provided ample opportunity for teachers to learn. Teachers increased their participation in their mentors' laboratories. Some teachers experienced the culture of multiple laboratories and mentors. Others cultivated deep relationships that crossed over the three summers. Teachers were trusted and valuable contributors to their mentors’ research projects. Teachers learned about how science is done but did not change their understanding of the tenets of the nature of science. Instead, they reinforced the understandings they brought with them. Doing science is not enough on its own for teachers to shift their conceptual understanding of the nature of science.

Scientific research experiences for teachers are not a mere publicity stunt for the laboratory, nor do teachers consider them just an opportunity to supplement their salaries. This study showed how teachers learned and participated in the laboratory and how that learning impacted their classroom teaching. Both the scientists and the teachers benefited from their collaboration. Students benefited from knowledgeable and confident teachers, more capable of facilitating inquiry and student-led research projects. Scientific research experiences are a critical component of the professional development of practicing teachers.

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APPENDIX

Appendix A: Pilot Data From Science Education Professional Development Used To Inform the Study

Data Source	Origin	When	Variable	Analysis
The Nature and Implications of Science/Technology	Salish I	pre/post	NOS	Quantitative/Likert
Implementation of Research Project	Hemler, 1997	pre/post	Classroom	Quantitative/Likert
Research Self-Assessment	Hemler, 1997	pre/post	LPP/NOS	Quantitative/Likert
The Nature of Science and Science Teaching	Hemler, 1997	pre/post	NOS	Quantitative/Likert
Summative Survey	Self-constructed	post	LPP/NOS/Classroom	Open-ended & Likert

Appendix B: Semi-structured Interview Questions – Version 1

1. Suppose I was observing you at work in the laboratory. What would I see during the eight weeks you are here?

2. Would you say that conducting scientific research in a professional laboratory as a teacher is different than you expected?

3. How have your skills as a researcher developed since your first summer in the program?

4. Some people would argue that you are not given much of a chance to pursue your own ideas for research. How would you respond to such a statement?

5. How important is it to you that you pursue original research questions in the laboratory?

6. What have you learned about your mentor scientist as a person during your time at the laboratory?

7. How has your view of scientific research changed as a result of your participation in this program?

8. What do you believe the ideal high school classroom would look like?

9. If you could change one thing about your relationship with your mentor, what would it be?

10. What new projects have you started at your home school since beginning in this research program?

11. Some people believe that participating in scientific research does not change how you teach your students. Would you agree or disagree?

12. How has your students' perception of you as a teacher changed as a result of your participation in research?

Appendix C: Semi-structured Interview Questions – Version 2

Semi-Structured Interview Questions

The following questions are meant to focus our conversation about your experiences in the LSTPD/ACTS program. Your answers may lead me to ask other unscripted questions to clarify or elaborate on what you have shared. If you are uncomfortable with any of these questions you may of course decline to comment. If you have questions about what I am trying to ask, feel free to email or call me in advance of the interview, or to ask me during the interview.

Again, thank you so very much for volunteering your time to participating in this project. I am grateful for your cooperation!

Matthew Perkins, A.B.D.
Theory and Practice in Teacher Education, The University of Tennessee

1. Prior to your time at Oak Ridge National Laboratory, what experiences did you have conducting scientific research, either on your own, as part of a course, or with a mentor?

2. Briefly describe the research project(s) you were involved with. Suppose I had observed you at work in the laboratory. What would I have seen during the three years you participated in LSTPD/ACTS?

3. Would you say that conducting scientific research in a professional laboratory as a teacher is different than you expected?

4. How did your skills as a researcher develop since your first summer in the program?

5. Some people would argue that in a program like LSTPD/ACTS you are not given much of a chance to pursue your own research ideas. How would you respond to such a statement?

6. How important was it to you that you pursue original research questions in the laboratory, questions that may never have been researched or fully answered before your work?

7. What did you learn about your mentor scientist as a person during your time at the ORNL?

8. If you could have changed one thing about your relationship with your mentor scientist while you were at ORNL, what would it have been?

9. You were a part of a cohort of science teachers all conducting research. How did that cohort contribute to your experience in LSTPD/ACTS? How has it continued since the completion of the program?

10. How did your views of scientific research change as a result of your participation in LSTPD/ACTS?

11. What do you believe the ideal high school classroom would look like, in design, equipment, and curriculum?

12. What new projects did you start at your home school after beginning your research program?

13. Some people believe that participating in scientific research does not change how teachers actually teach their students. Based on your experiences, would you agree or disagree?

14. How has your students' perception of you as a teacher changed as a result of your participation in research? Other teachers? Your administration?

Appendix D: Correspondence of Interview Questions to Research Questions

Research Questions

A. To what degree are the teachers able to increase their participation, thus becoming more valuable to pursuing original research designs and sensemaking of data?
B. To what degree are the teachers learning about the nature of science through participation in scientific research?
C. How is participation in authentic scientific research impacting the teachers' classrooms and professional careers?

Semi-Structured Interview Questions

The teachers' prior experience conducting research (B)

1. Prior to your time at Oak Ridge National Laboratory, what experiences did you have conducting scientific research, either on your own, as part of a course, or with a mentor?

The teachers' experience in general at the laboratory (A and B)

2. Briefly describe the research project(s) you were involved with. Suppose I was observing you at work in the laboratory. What would I have seen during the three years you participated in LSTPD/ACTS?
3. Would you say that conducting scientific research in a professional laboratory as a teacher is different than you expected?

The latitude the teachers have to pursue and interpret their own research questions (A)

4. How did your skills as a researcher develop since your first summer in the program?
5. Some people would argue that in a program like LSTPD/ACTS you are not given much of a chance to pursue your own ideas for research. How would you respond to such a statement?
6. How important was it to you that you pursue original research questions in the laboratory, questions that may never have been researched or fully answered before your work?

The relationship between the teacher and the mentor scientist (A)

7. What have you learned about your mentor scientist as a person during your time at ORNL?
8. If you could have changed one thing about your relationship with your mentor scientist while you were at ORNL, what would it have been?

The evolution of teachers' understanding of the nature of science (B)

9. How did your views of scientific research change as a result of your participation in LSTPD/ACTS?

The impact of conducting research on the teachers' classrooms and careers.(C)

10. You were a part of a cohort of science teachers. all conducting research. How did that cohort contribute to your experience in LSTPD/ACTS? How has it continued since the completion of the program?
11. What do you believe the ideal high school classroom would look like, in design, equipment, and curriculum?
12. What new projects have you started at your home school since beginning in this research program?
13. Some people believe that participating in scientific research does not change how teachers actually teach their students. Based on your experiences, would you agree or disagree?
14. How has your students' perception of you as a teacher changed as a result of your participation in research? Other teachers? Your administration?

Appendix E: VNOS C

1. What, in your view, is science? What makes science (or a scientific discipline such as physics, biology, etc.) different from other disciplines of inquiry (e.g., religion, philosophy)?

2. What is an experiment?

3. Does the development of scientific knowledge **require** experiments?

    - If yes, explain why. Give an example to defend your position.
    - If no, explain why. Give an example to defend your position.

4. After scientists have developed a theory (e.g., atomic theory, evolution theory), does the theory ever change?

    - If you believe that scientific theories doe not change, explain why. Defend your answer with examples.
    - If you believe that scientific theories do change: (a) Explain why theories change. (b) Explain why we bother to learn scientific theories. Defend your answer with examples.

5. Is there a difference between a scientific theory and a scientific law? Illustrate your answer with an example.

6. Science textbooks often represent the atom as a central nucleus composed of protons (positively charged particles) and neutrons (neutral particles) with electrons (negatively charged particles) orbiting the nucleus. How certain are scientists about the structure of the atom? What evidence **do you think** scientists used to determine what an atom looks like?

7. Science textbooks often define a species as a group of organisms that share similar characteristics and can interbreed with one another to produce fertile offspring. How certain are scientists about their characterization of what a species is? What specific evidence **do you think** scientists use to determine what a species is?

8. It is believed that about 65 million years ago the dinosaurs became extinct. Of the hypotheses formulated by scientist to explain the extinction, two enjoy wide support. The first, formulated by one group of scientists, suggests that a huge meteorite hit the earth 65 million years ago and led to a series of events that caused the extinction. The second hypothesis, formulated by another group of scientists, suggests that massive and violent volcanic eruptions were responsible for the extinction. How are these **different conclusions** possible if scientists in both groups have access to and use the **same set of data** to derive their conclusions?

9. Some claim that science is infused with social and cultural values. That is, science reflects the social and political values, philosophical assumptions, and intellectual norms of the culture in which it is practiced. Others claim that science is universal. That is, science transcends national and cultural boundaries and is not affected by social, political, and philosophical values, and intellectual norms of the culture in which it is practiced.

   - If you believe that science reflects social and cultural values, explain why. Defend your answer with examples.
   - If you believe that science is universal, explain why. Defend your answer with examples.

10. Scientists perform experiments / investigations when trying to find answers to the questions they put forth. Do scientists use their creativity and imagination during their investigations?

   - If yes, then at what stages of the investigations do you believe scientists use their imagination and creativity: planning and design, data collection, after data collection? Please explain why scientists use imagination and creativity. Provide examples if appropriate.
   - If you believe that scientists do not use imagination and creativity, please explain why. Provide examples if appropriate.

Appendix F: Online Version of the VNOS-C

1. Describe in your own words what science is to you? What makes science (physics, biology, etc.) different from other disciplines (e.g. religion, philosophy, social sciences)?

2. Describe an experiment. Please give an example.

3. Do you think that the development of scientific knowledge requires experimentation? When might it require or not require experimentation? Please explain.

4. After scientists have developed a theory (e.g., atomic theory, evolution theory), does the theory ever change?

   a) YES - If you believe that scientific theories **do** change:
   b) NO - If you believe that scientific theories do not change, explain why. Defend your answer with examples.

   4a) Explain why theories change.
   4b) Explain why we bother to learn scientific theories. Defend your answer with examples.

5. Do you think there is a difference between scientific theories and scientific laws? Please explain your answer and give an example if appropriate.

6. Science textbooks often represent the atom as a central nucleus composed of protons (positively charged particles) and neutrons (neutral particles) with electrons (negatively charged particles) orbiting the nucleus.

   a) How certain are scientists about the structure of the atom?
   b) What evidence do you think scientists used to determine what an atom looks like?

7. Science textbooks often define a species as a group of organisms that share similar characteristics and can interbreed with one another to produce fertile offspring. How certain are scientists about their characterization of what a species is? What specific evidence do you think scientists use to determine what a species is?

8. It is believed that about 65 million years ago the dinosaurs became extinct. Of the hypotheses formulated by scientist to explain the extinction, two enjoy wide support. The first, formulated by one group of scientists, suggests that a huge meteorite hit the earth 65 million years ago and led to a series of events that caused the extinction. The second hypothesis, formulated by another group of scientists, suggests that massive and violent volcanic eruptions were responsible for the extinction. Explain how these different conclusions are possible if scientists in both groups have access to and use the same set of data to derive their conclusions.

9. Some claim that science is infused with social and cultural values. That is, science reflects the social and political values, philosophical assumptions, and intellectual norms of the culture in which it is practiced. Others claim that science is universal. That is, science transcends national and cultural boundaries and is not affected by social, political, and philosophical values, and intellectual norms of the culture in which it is practiced. What are your beliefs about science? (Choose one of the three and then please answer the followup).

   a) Science reflects **social and cultural values**.
   b) Science is **universal.**
   c) Science is a combination of **both**.

   9a) Please explain what you mean when you say that science reflects **social and cultural** values. Illustrate your response with examples.

   9b) Please explain what you mean when you say that science is **universal**. Illustrate your response with examples.

   9c) Please explain what you mean by science **both** reflecting social and cultural values and being universal. Illustrate your response with examples.

10. Scientists perform experiments and investigations when trying to find answers to the questions they put forth. Do scientists use their creativity and imagination during their investigations?

   a) Scientists do **not** use imagination or creativity in their work.
   b) Scientists **do** use imagination and creativity in their work.

   10a) What leads you to conclude that science does not involve creativity or imagination? Use examples if appropriate.

   10b) At what stages of the investigations do you believe scientists use their imagination and creativity: planning and design, data collection, after data collection? Provide examples if appropriate.

Appendix G: Cursory Codes for Use with Semi-Structured Interview Data

Category	Subcategory
Legitimate peripheral participation	community of practice/CoP Participation Learning / identity construction Apprenticeship Increasing participation Mentors / “old timers” Access Cohort / “newcomers”
Nature of science	Empirical nature Observation / Inference Theory vs. Law Creative / Imaginative Theory laden Social / Cultural Scientific Method Tentative
Classroom	Confidence Pedagogy Received by teachers Received by principals Beliefs / philosophy of teaching Transfer Students Motivation / enthusiasm Financial incentive Impact on teaching Impact on students Laboratory vs. classroom Prior experiences Research changes teaching? Impact on career

Appendix H: Rubric for Poster Analysis

Year

Title:

Author(s):

Sections:

- objective
- procedure
- methods
- results
- conclusions
- implications
- acknowledgements

Inscriptions:

- photographs
- graphs
- tables
- charts
- drawings

Notes:

Appendix I: VNOS-C Coding Matrix

Name: ______________________________ Pretest ________ Posttest ________

	Empirical NOS	Scientific Method	**Structure/Aim** Experiments	**Prior Expectations** in Experiments	Validity of **observation** based	**Tentative** NOS	Theories v. Laws	**Nature** of Scientific Theories	**Functions** of Scientific Theories	Logic of **Testing** Scientific Theories	**Creative** and **Imaginative** NOS	**Inference** and theoretical entities	**Theory-laden** NOS	**Social & Cultural** embeddedness of NOS
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H1**	**H2**	**H3**	**I**	**J**	**K**	**L**
Q1														
Q2														
Q3														
Q4														
Q5														
Q6														
Q7														
Q8														
Q9														
Q10														

N = naïve, D = developing, I = informed

Coded by: ______________________________ Date: ______________

Appendix J: Sample Scored VNOS-C Coding Matrix

Name: Connie

Pretest ____ Posttest X

	Empirical NOS	Scientific Method	**Structure/Aim** Experiments	**Prior Expectations** in Experiments	Validity of **observation** based	**Tentative** NOS	Theories v. Laws	**Nature** of Scientific Theories	**Functions** of Scientific Theories	Logic of **Testing** Scientific Theories	**Creative** and **Imaginative** NOS	**Inference** and theoretical entities	**Theory-laden** NOS	**Social & Cultural** embeddedness of NOS
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H1**	**H2**	**H3**	**I**	**J**	**K**	**L**
Q1	**N**	**N**												
Q2			**N**											
Q3					**N**									
Q4						**I**								
Q5							**N**							
Q6												**I**		
Q7												**I**		
Q8													**D**	
Q9														**N**
Q10											**I**			

N = naïve, D = developing, I = informed

Coded by: Perkins

Date: 8/30/2009

VITA

Matthew Phillip Perkins was born in Detroit, Michigan on September 8, 1976. He began reading at an early age and was clinically-certified as gifted at age four. When he was nine, his family moved to his grandparents' small farm in Jellico, Tennessee. Because the gifted program at his elementary school was cut, he was double promoted from fifth to sixth grade in the middle of the year. He attended Campbell County Comprehensive High School during his freshman year and the first half of his sophomore year. He transferred midyear to Knoxville Central High School, from which he graduated with honors in 1993. He accepted a full tuition scholarship to study engineering at Berea College.

By his sophomore year of college, Matthew's interest had turned to physics and music. He changed majors to physics and spent the summer following his junior year in an engineering CO-OP experience designing gas burners. He spent the fall at Argonne National Laboratory as an undergraduate intern investigating methods of manufacturing and testing superconductive wires. After careful consideration of his deep interest in teaching, he returned to Berea College the following spring and switched majors to education. A year later he graduated with a degree in physics and education and minor in mathematics.

His first teaching assignment was in physics and physical/earth/space science at Somerset Independent High School. The following July he pursued his lifelong interest in astronomy by assuming the directorship of the Robeson Planetarium and Science

Center in Lumberton, North Carolina. Highlights of his four year tenure included production and presentation of the first Black History month program in the facility's thirty year history, the addition of Spanish-language programming, and oversight of a five year, $100,000 plan for renovating the facility. He also partnered with a children's museum in a grant that hired twenty minority high school students to design and teach science camps for K-3 students and to design planetarium shows and exhibits for the science center over the span of two summers.

Also while in Lumberton he completed his M.A.Ed in Science Education at the University of North Carolina at Pembroke, a historically Native American school. After earning his Master's he taught adjunct astronomy and physics courses for the university. He taught as an online high school instructor for the Cumberland County WebAcademy, designing an astronomy course and teaching physics, algebra II, and SAT math prep over a five year period.

In 2003 Matthew accepted a dual-appointment assistantship at the University of Tennessee in Education and Engineering, serving as a graduate assistant for Dr. Claudia T. Melear in Theory and Practice in Teacher Education and as a recruiter for the engage1st engineering scholarship program, directed by Dr. Elaine Seat.

In 2004 Matthew was offered his dream secondary teaching assignment: the opportunity to teach physics at Oak Ridge High School. In addition to teaching general physics courses, he has cotaught AP Physics B with Dr. Peggy Bertrand for the past three years and taught one year of AP Physics C.

He was introduced to Christina Ryan during his junior year of college. The two were married in October 1998, shortly after he started his first teaching position. In July 2005, they welcomed their first child, Bethany Joy. The three currently reside in Oak Ridge, TN.