PROFESSIONAL DEVELOPMENT BY SCIENTISTS
AND TEACHERS’ UNDERSTANDING OF THE
NATURE OF SCIENCE

A Thesis in
Curriculum and Instruction
by
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Abstract

The educational literature suggests that the success of professional development is contingent upon both a professional developer’s presentation of the curriculum and his/her comprehension of the complex interactions that occur between instructor and the adult learner. While these suggestions appear forthright and logical, very little research has been conducted to demarcate how professional development approaches defined by these notions impact teacher knowledge.

This study investigates the effects of scientist-delivered teacher professional development on teachers’ understanding of the nature of science. Using a mixed-method comparative case study, my goal was to build theory focusing specifically on two dimensions of professional development: the pedagogical approaches used by the scientist-instructors and their views/treatment of teachers as professionals or as technicians. Seven credit-bearing summer courses from multiple scientific disciplines were studied, and each course shared a number of important features (duration, general format, teacher recruitment and admission, location, number of participants, etc.); consequently, they comprise a unique dataset for comparative research on science teacher professional development. A wide variety of data collection approaches were used, including interviews, questionnaires, a VNOS instrument, and systematic classroom observation by ten trained observers (each course was continuously observed by at least two observers). Analysis shows that teachers were more likely to experience change in their views about the nature of science in courses in which they were treated as professionals, compared to courses in which they were treated as technicians. It also shows that syllabi and participant reports tend to overstate the use of inquiry methods when reviewed in the light of close classroom observation.

By recognizing and defining professional development contexts that build teachers’ knowledge, this study suggests how university-based professional development for science educators can be improved, helping to actualize the collaborative relationships that need to exist between staff developers and discipline specialists. In conclusion, I use the findings from this study to expand the current literature and suggest how improved university-based professional development contexts can be created.
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Chapter 1 – Getting Started

**Defining the Research Problem**

This study explores the impact that professional development scenarios have on teachers’ learning. Specifically, this research focuses on how the complex interactions that occur between professional development instructors and adult learners, identified through the educational leadership literature, and how different pedagogical and curricular approaches, identified in the science education literature, affect 5-12 science teachers’ understanding of the nature of science.

**Merging the Two Fields**

By utilizing both bodies of literature mentioned above, there is the potential to recognize multidimensional strategies that enable professional developers to identify contexts and confidently combine strategies that have the potential to improve science teaching and learning. Even when professional developers are experts in their respective scientific fields, they have the potential to build instructional contexts that are “antithetical to the content” (Carlsen, 1991, p. 137). Professional development for science educators should identify the best contexts for instruction (Brown, Collins, & Duguid, 1989), an aspect of planning that requires both a knowledge of general educational theories and methods, and content qualifications (Shulman, 1986b).

Designing and implementing effective professional development offerings for science educators has proven to be a difficult task, because professional developers, like teachers, seldom have the time or inclination to write about their work, and because research that addresses our knowledge of successful professional development strategies within the structure for science education is rather limited (Loucks-Horsley, Hewson,
Love, & Stiles, 1998, p. xii). In the second edition of *Designing Professional Development for Teachers of Science and Mathematics* (2003), the authors note that the first edition (1998) successfully synthesized and codified “what outstanding and effective professional developers of science education do when they design programs” for science educators (2003, p. xiii). However, since the release of the first edition of this seminal book, very little research has occurred at the intersection of the extensive literature on adult learning and staff development and the literature produced by the scientists and science educators who design and conduct professional development programs for teachers. Because the authors in both the first and second editions do not identify and successfully join these seemingly disparate bodies of literature, they do not elucidate how many of the “general characteristics of effective professional development” impact teacher learning and understanding (1998, p. xii).

Discipline specific professional developers experience a contradictory and scattered existence because of this persistent gap within the educational literature: Content specialists frequently receive training in a content area yet remain largely unaware of the literature on adult learning and staff development, while staff developers maintain an understanding of the adult learning literature but are unable to effectively apply these concepts to teachers who are content specialists (Loucks-Horsley et al., 1998; Shulman, 1986b).

Understanding of the NOS as an Outcome

*When people know how scientists go about their work and reach scientific conclusions, and what the limitations of such conclusions are, they are more likely to react thoughtfully to scientific claims and less likely to reject them out of hand or accept them uncritically.*

*Once people gain a good senses of how science operates – along with a basic inventory of key science concepts as a basis for learning more*
later – they can follow the science adventure story as it plays out during their lifetimes.

The images that many people have of science and how it works are often distorted. The myths and stereotypes that young people have about science are not dispelled when science teaching focuses on the laws, concepts, and theories of science. Hence, the study of science as a way of knowing needs to be made explicit in the curriculum” (American Association for the Advancement of Science, 1993, p. 3)

Although knowledge of general educational theories and methods is essential, it plays a secondary role in the qualifications of the content teacher (Shulman, 1986b); for science teachers learning science involves being initiated into the ideas and practices of the scientific community and making these ideas and practices meaningful at an individual level (Driver, Asoko, Leach, Mortimer, & Scott, 1994). The importance of helping teachers develop and deliver informed views of the nature of science as a central goal for K – 12 science education is supported by education research (American Association for the Advancement of Science, 1993; Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002; National Research Council, 1996a): instructors who have an understanding of a given subject allow students to engage in discourse more often, are more likely to ask higher level cognitively based questions, and are better suited to evaluate student progress (Carlsen, 1988; National Research Council, 2001).

The National Science Education Standards (1996a) content standards “outline what students should know, understand, and be able to do in natural science” which includes a comprehensive understanding of the “history and nature of science,” (National Research Council, 1996a, pgs. 103-104): Students need to understand that “science reflects its history and is an ongoing, changing enterprise” (National Research Council, 1996a, p. 107). Although the content standards are a complete set of outcomes for
students and delineate what aspects of the nature of science should be introduced into the curriculum (Table 1), they do not suggest how teachers come to a knowledge of the nature of science and they do not prescribe specific curricula or pedagogical approaches that teachers should use in their classroom regarding the nature of science (National Research Council, 1996a).

<table>
<thead>
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<th>Table 1: Nature of Science Standards (National Research Council, 1996a, p. 108)</th>
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<td>Levels K-4</td>
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Loucks-Horsley advocates that “effective science professional development (should) reflect the nature of the disciplines ... (so that) teachers in turn can create experiences with their students in the classroom that reflect the nature of doing and learning science and mathematics” (2003, p. 43). Teachers with a better understanding of the characteristics of the work of scientific work are more likely to begin engaging students in challenging mathematical problems and scientific inquiry (Loucks-Horsley, 2003).

Understanding the NOS within the context of University-Based Professional Development (UBPD)

Broad suggestions have been made that science teacher professional development would be most effective if “practicing teachers study and work with experienced teachers, researchers, and teacher educators who effectively teach science,” allowing teachers to recognize that “science is not just a body of knowledge, but a paradigm...
through which to see the world” (American Association for the Advancement of Science, 1998, p. 202). The AAAS also suggests that university instructors involved in science teacher professional development should rethink the way they organize curricula and instruct professional development (1998, p. 209). To pursue this end, the Committee on Science and Mathematics Teacher Preparation has proposed that “many more scientists… must become well informed enough to be involved with local and national efforts to provide the appropriate content knowledge and pedagogy of their discipline to current and future teachers” (National Research Council: Committee on Science and Mathematics Teacher Preparation, 2001, p. 88). A review of the research from the last 25 years concludes that comprehensive science teacher professional development is dependent upon the successful interaction between the university and K-12 communities (National Research Council: Committee on Science and Mathematics Teacher Preparation, 2001). Such an interaction can be realized through partnerships between university scientists and K-12 science teachers (National Research Council, 1996a, 1996b); however, creating these partnerships has proven difficult due to the dysfunctional relationship that often characterized the relationship between K-12 schools and the university over the past 100 years (DeBoer, 1991; Rudolph, 2000; Schwab & Brandwein, 1962).

Before more university scientists become involved in professional development, science educators should first define the meaning of becoming “well informed enough …to provide the appropriate content knowledge and pedagogy of their discipline” (National Research Council: Committee on Science and Mathematics Teacher Preparation, 2001, p. 88). Science educators must also provide a research-supported
definition of “effectively teaching science” in the context of university-based professional development (American Association for the Advancement of Science, 1998). Science education researchers must provide clarity on how university instructors involved in K – 12 science teacher professional development can/might rethink the way they organize curricula and instruct professional development (American Association for the Advancement of Science, 1998). Ultimately, science educators must answer the question, “What kind of professional development contexts best support and reflect the nature of the different scientific disciplines?” (Loucks-Horsley, 2003).

**Pragmatism and Mixed Method Evaluation Research**

A researcher should first identify the theoretical drive of a project (Morse, 2003). The theoretical drive of this study is both exploratory and inductive, requiring that the research problem (Chapter 1) and environment (Chapter 2) first be defined and then indicate to the reader how “explicit” (Creswell, 2003b, p. 208), “unorthodox and innovative” (Jick, 1979) procedures will be selected and applied to this unique problem.

The funding for my dissertation came from a state consortium of the National Aeronautic and Space Administration (NASA), which has a goal of promoting professional development programs that support a strong science, mathematics, and technology education base from elementary through secondary levels (NASA, 2004). Both the NSF and NASA have become increasingly interested in the evaluation of the progress and effectiveness of the professional development they fund: Project staff, participants, local stakeholders, and decision makers need to know how funded projects

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1 Similarly, the National Science Foundation (NSF) has also begun to fund professional development programs for K-12 educators that uphold the health and continued vitality of the Nation's science, technology, engineering and mathematics education by providing leadership in the effort to improve K-12 education in these areas.
are contributing to knowledge and understanding of mathematics, science, and technology (Sharp & Frechtling, 1997). The NASA consortium hired me to evaluate their university based professional development programs for K-12 educators, and it is within this evaluative context\(^2\) that I was fortunate to be able to collect my the data for my dissertation.

Because the target audience for this evaluative research was scientists, who often depend on quantitative studies, and educators, who often conduct naturalistic qualitative studies, I decided to implement a mixed method study. This decision has ample precedent; in science education, “Experienced evaluators have found that most often the best results are achieved through the use of mixed method evaluations, which combine quantitative and qualitative techniques” (Sharp & Frechtling, 1997).

> During the past three decades, evaluation research has emerged as an important and distinctive field of research, largely because funding has been available for the systematic evaluation of educational programs, including many in the field of science education. While it might be argued that evaluation studies do not necessarily include an investigatory or research component, these evaluation studies increasingly have become well-designed so that they do not only provide information to assist decision makers in their judgments, but they also provide evidence and findings that help in the understanding of educative processes and in making generalizations (Keeves, 1998, pgs. 1142 - 1143).

Field methods can contribute to evaluations with respect to the validation of results, the interpretation of statistical relationships, and the clarification of puzzling findings (Jick, 1979). Analytic methods can maximize validity and broaden the applicability of systemic studies (Solomon, 1991). In short, depending on the design, mixed methods can account for both internal consistency and a degree of external validity (Jick, 1979, p. 603).

\(^2\) Chapter 2, Selecting Cases, will define the context in detail.
Dissertation research studies are conventionally grounded in either a qualitative or quantitative research paradigm. “Graduate training usually prepares us to use one method or another as appropriate and preferred, but not to combine methods effectively” (Jick, 1979, p. 602). Nevertheless, the era of mixed method research being an anomaly within another research paradigm has passed, and the mixed method research paradigm has emerged (Creswell, 2003b; Kuhn, 1996; Miles & Huberman, 1994; Shavelson & Towne, 2002; Tashakkori & Teddlie, 2003). Mixed method research departs from these “outmoded” distinctions between qualitative and quantitative research by being grounded in pragmatism, derived from the work of Peirce, James, Mead, and Dewey. Pragmatism prioritizes the research problem, not the research method, and the researcher uses all appropriate approaches to understand this problem (Cherryholmes, 1992; Creswell, 2003b; Rzasa, 2003).

The pragmatic position also maintains that there are philosophical differences between various paradigms of inquiry. But, for the pragmatist, these philosophical assumptions are logically independent and therefore can be mixed and matched, in conjunction with choices about methods, to achieve the combination most appropriate for a given inquiry problem (Greene & Caracelli, 1997, p. 8).

And while the individual methods of mixed methods derive their legitimacy from these divergent research paradigms, “these paradigm differences do not really matter very much to the practice of social inquiry, because paradigms are best viewed as descriptions of, not prescriptions for, research practice. . . . What should drive all methodological decisions in social inquiry – is the inquiry problem’s practical demands” (Greene & Caracelli, 1997, p. 8).
Although the term “mixed methods” is fairly recent (Creswell, 2003b; Tashakkori & Teddlie, 2003), some educational researchers have been grounded in pragmatism, blending quantitative and qualitative methods, for more than a century. Dewey attempted to mix aspects of naturalistic research and experimental design at his Lab School and throughout his career, and elucidated this notion by stating that educational “behavior is serial, not a mere succession. It can be resolved – it must be – into discrete acts, but no act can be understood apart from the series to which it belongs” (Dewey, 1930, p. 412, as cited through Solomon (1991)). Campbell and Fiske (1959), commonly cited as the modern day pioneers of mixed methods, argued that more than one method should be used in the validation process to ensure that variance is reflective of the trait and not the method (Creswell, 2003b; Jick, 1979). Jick (1979) was one of the first to “indicate how this prescribed triangulation is actually performed and accomplished” (p. 602) in his seminal article, *Mixing Qualitative and Quantitative Methods: Triangulation in Action.*

Although mixed methods have been slow to take root in the educational community, other scholars in the social sciences, policy makers, and funding agencies recognize this research genre as legitimate:

> Evaluators are generally pragmatists (at least those who continue to receive evaluation contracts); they understand that evaluation research is a series of decisions that are compromises based on logistics, feasibility, stakeholder interests, the value stance of the evaluator, time, and other resources (Rallis & Rossman, 2003, p. 492).

Both Keeves and Rallis and Rossman indicate that mixed method evaluative research falls somewhere between “more theoretical or pure purposes” and “purely pragmatic.” This hybridization demands that evaluative researchers working in applied fields such as business, health care, and education design and conduct studies that rely on
multiple methods in order “to understand complex social phenomena” (Rallis & Rossman, 2003, p. 492):

> Pragmatism, however, does not imply a shameless disregard for the assumptive worlds from which specific methods derive; instead, it serves as a reminder that the overall purpose of evaluation is to make judgments about the merit and worth of social programs and to do so with integrity, rigor, and ethics (Rallis & Rossman, 2003, p. 492).

Specific to science education, Keeves mentions several forms of evaluative research that can utilize mixed methods, including instructional studies that evaluate the effectiveness of investigatory activity and laboratory work in science, and science education programs that couple course development and “high-quality evaluation studies” (Keeves, 1998, p. 1143).

**Neither Theory or Hypothesis**

The research design that serves as the template of my dissertation delineates a process for building theory using mixed methods (Eisenhardt, 1989). Kathleen Eisenhardt’s *Process of Building Theory from Case Study Research* (Table 2) recognizes that theory building is not a method based solely on interview data (Morse, 2003); saturation, often referred to as “closure,” can be achieved using other sources of data (Eisenhardt, 1989; Glaser, 1978; Glaser & Strauss, 1965; Jick, 1979; Strauss & Corbin, 1998).

Eisenhardt’s research design is not an “ad hoc mixing of methods” (Morse, 2003) or “muddled methods” (Stern, 1994); it develops theory through procedures widely accepted in the social sciences (Eisenhardt, 1989; Yin, 2003). Evaluative research usually “entails three primary activities: description, comparison, and prediction” (Rallis
Eisenhardt’s model of theory building follows this framework and expands the definition of “prediction” to include the potential to culminate into theory building (Creswell, 2003a; Eisenhardt, 1989; Morse, 2003; Yin, 2003).

This theory-building model requires that the researcher begin as close as possible to the ideal of no theory under consideration and no hypothesis to test (Eisenhardt, 1989; Strauss & Corbin, 1998). Eisenhardt recognizes that it is impossible to approach a problem with a completely “clean theoretical slate” (p. 536), and suggests that researchers interact with extant literature to identify potentially important variables throughout the formation of a problem. However, it is important for the researcher to avoid thinking about specific relationships between variables and theories as much as possible, especially at the beginning of the process.

The use of *a priori* constructs (described in a subsequent section) is in line with Strauss and Corbin’s notion of emergence, because this existing typology is “building on or continuing with (the researcher’s) previous studies” and will continue to be “established” throughout the ongoing evaluation (Strauss & Corbin, 1998, p. 33). This research approach promotes a “true interplay” between qualitative and quantitative methods: “The qualitative should direct the quantitative and the quantitative feedback into the qualitative in a circular, but at the same time evolving, process with each method contributing to the theory in ways that only each can” (Strauss & Corbin, 1998, p. 34).

Eisenhardt’s “Process of Building Theory from Case Study Research” is consistent with both Creswell’s *concurrent triangulation strategy* for mixed method

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3 While Creswell’s other models of mixed-method designs have been criticized for aligning quantitative methods with quantitative paradigms and qualitative methods with qualitative paradigms, obscuring “how
design, as seen in Figure 1 (2003a; 2003b) and Caracelli and Greene’s holistic design, a sub-category of their mixed-method integrated design.

Creswell’s concurrent triangulation design strategy merges features common in hypothesis testing research, such as problem definition and construct validation, with features unique to multiple-case studies, such as “replication logic” (Eisenhardt, 1989; Yin, 2003). This process is “especially appropriate to new topic areas” as is the case with this study (p. 532), and the resultant theory is often “novel, testable, and empirically valid” (Eisenhardt, p. 532). This strategy is selected as a model when a researcher uses separate qualitative and quantitative methods as a means to offset the weaknesses of one method with the strengths of another method by confirmation and cross-validation of findings within a single study. This research model assigns equal value to methods, enables the researcher to gather multiple types of data simultaneously during a time-limited data collection phase, and can provide a comprehensive analysis of the research problem without drastically altering an environment.

According to Caracelli and Greene, this methodology also falls under the broader category mixed-method integrated design, and the subcategory of holistic design. Integrated designs attain a greater integration of different method types than other mixed-method designs by integrating “elements of disparate paradigms and have the potential to produce significantly more insightful, even dialectically transformed, understandings of the phenomenon under investigation” (Caracelli & Greene, 1997, p. 23). Holistic designs “highlight the necessary interdependence of different methodologies for understanding both method types can be used within a single inquiry framework to construct knowledge” (Caracelli & Greene, 1997, p. 21), this model allows methods from dissimilar paradigms to be mixed, while potentially producing meaningful outcomes (Caracelli & Greene, 1997, p. 23).
complex phenomena fully” (p. 23). There is simultaneity in the integration of methods in these designs, rather than a sense of taking turns.

This genre of design often takes the form of a conceptual framework that guides the design and implementation of the whole study. Using concept maps (Maxwell, 1996; Trochim, 2002a) at the outset of a study can provide a substantive framework for integrating disparate methods, meanings, and understandings” (Caracelli & Greene, 1997). This framework is further developed at the end of this chapter and culminates with Figure 4.

The tradition of triangulation, used in the data analysis of both Creswell and Caracelli and Greene’s mixed methods designs, is familiar to most researchers and can result in “well-validated and substantiated findings” (Creswell, 2003b, p. 217). Triangulation between (across) methods is a “vehicle for cross validation when two or more distinct methods are found to be congruent and yield comparable data.” For social scientists, this involves the use of mixed methods to examine the same dimension of a research problem (Jick, 1979, p. 602). Bogdan and Biklen (2003) point out that if these different methods are unable to examine the same dimension of the research and the researcher is unable to ascertain the necessary level of construct validity, rich description can be used to organize and redirect the data analysis. Jick gives further examples of researchers evaluating the effectiveness of an educational setting through interviews, observations, and evaluative performance records.
### Table 2 – Chapter Outline of Dissertation

**Process of Building Theory from Case Study Research** (Eisenhardt, 1989, p. 533)

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<thead>
<tr>
<th>Step</th>
<th>Activity</th>
<th>Reason</th>
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<td>Getting Started (Chapter 1)</td>
<td>• Defining the research problem</td>
<td>• Focuses efforts</td>
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<td></td>
<td>• Pragmatism MME Research</td>
<td>• Provides better grounding of construct measures</td>
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<tr>
<td></td>
<td>• Neither theory or hypothesis</td>
<td>• Retains theoretical flexibility</td>
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<td></td>
<td>• Possibly of <em>a priori</em> constructs</td>
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<td>• Focuses efforts</td>
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<td>• Retains theoretical flexibility</td>
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<tr>
<td>Selecting Cases (Chapter 2)</td>
<td>• Defining the context and specifying the population</td>
<td>• Constrains extraneous variation and sharpens external validity</td>
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<td></td>
<td>• Theoretical, not random sampling</td>
<td>• Focuses efforts on theoretically useful cases – i.e., those that replicate or extend theory by filling conceptual categories</td>
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<td>Crafting Instruments and Protocols</td>
<td>• Multiple data collection methods</td>
<td>• Strengthens grounding of theory by triangulation of evidence</td>
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<tr>
<td>(Chapter 3)</td>
<td>• Qualitative and quantitative data combined</td>
<td>• Synergistic view of evidence</td>
</tr>
<tr>
<td></td>
<td>• Multiple investigators</td>
<td>• Fosters divergent perspectives and strengthens grounding</td>
</tr>
<tr>
<td>Entering the Field and Within Case</td>
<td>• Overlap data collection and analysis, including field notes</td>
<td>• Speeds analyses and reveals helpful adjustments to data collection</td>
</tr>
<tr>
<td>Observation/Analysis (Chapter 4)</td>
<td>• Flexible and opportunistic data collection methods</td>
<td>• Allows investigators to take advantage of emergent themes and unique case features</td>
</tr>
<tr>
<td></td>
<td>• Within-case analysis</td>
<td>• Gains familiarity with data and preliminary theory generation</td>
</tr>
<tr>
<td>Analyzing Cross Case Patterns and</td>
<td>• Cross-case pattern search using divergent techniques</td>
<td>• Forces investigators to look beyond initial impressions and see evidence thru multiple lenses</td>
</tr>
<tr>
<td>Shaping Hypotheses (Chapter 5)</td>
<td>• Iterative tabulation of evidence for each construct</td>
<td>• Sharpens construct definition, validity, and measurability</td>
</tr>
<tr>
<td></td>
<td>• Replication, not sampling, logic across cases</td>
<td>• Confirms, extends, and sharpens theory</td>
</tr>
<tr>
<td></td>
<td>• Search evidence for “why” behind relationships</td>
<td>• Builds internal validity</td>
</tr>
<tr>
<td>Reaching Closure through Enfolding</td>
<td>• Comparison with conflicting literature</td>
<td>• Builds internal validity, raises theoretical level, and sharpens construct definitions</td>
</tr>
<tr>
<td>Literature and Implications (Chapter 6)</td>
<td>• Comparison with similar literature</td>
<td>• Sharpens generalizability, improves construct definition, and raises theoretical level</td>
</tr>
<tr>
<td></td>
<td>• Theoretical saturation</td>
<td>• Ends process when marginal improvement becomes small</td>
</tr>
</tbody>
</table>
Figure 1: Visual model of research design.

Process of Building Theory from Case Study Research
Concurrent Triangulation Strategy (Creswell, 2003a, 2003b)

Beginning of Study

Time Line

Qualitative Data Collection and Ongoing Data Analysis

Getting Started - The Research Question
Selecting Cases
Crafting Instruments and Protocols
Entering the Field

Quantitative Data Collection and Ongoing Data Analysis

Summative Data Analysis: Data Results Compared - Triangulation

Shape Hypothesis
Enfolding Literature
Reaching Closure

End of Study
Possibility of a priori Constructs

A priori specification of constructs can also help shape the initial design of the theory-building research. Although this type of specification is not common in theory-building studies to date, it is valuable because it permits researchers to measure constructs more accurately. If these constructs prove important as the study progresses, then researchers have a firmer empirical grounding for the emergent theory. . . Although early identification of the research question and possible constructs is helpful, it is equally important to recognize that both are tentative in this type of research. No construct is guaranteed a place in the resultant theory, no matter how well it is measured. Also, the research question might shift during the research. . . . If these constructs prove important as the study progresses, then researchers have a firmer empirical grounding for the emergent theory. (Eisenhardt, 1989, p. 536)

In order to build theory, I needed to create a theoretical framework that would allow me to study professional development contexts through the separate science education and educational leadership literature lenses while simultaneously examining the interactions that occur4.

Mary Douglas, in her paper, *Cultural Bias* (1978), presents an analytic typology that creates a link between social organization and the specialization of roles within a society. Through this work she uses a vertical and a horizontal axis. The vertical axis is called the "group." The group is the measure of social organization, and this identifies the cohesiveness of the society. The horizontal axis is referred to as the "grid." An organization with "high-grid" tendencies limits its members' autonomy. Through the juxtaposition of the grid axis and group axis, Douglas creates a typology of four kinds of society. Because these categories or classification are representative of extremes, she

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4 As mentioned previously, different pedagogical and curricular approaches identified in the science education literature, and the complex interactions that occur between instructors and adult learners identified in the educational leadership literature.
suggests that real organizations or societies should be placed along a graded scale (Douglas, 1986), thus exhibiting a combination of attributes of the four types.

One year later, Burrell and Morgan (1979) developed a 2 X 2 typology in reviewing social science research literature, and developed a theory that helps explain how research paradigms impact approaches to social science research. Rossman and Rallis (2003) meticulously explicate how Burrell and Morgans’ continua and typology were derived. The application of the typology to study the impact of paradigms on research approaches appears to have many similarities to this research problem.

Dewey often used a similar strategy: using dichotomies initially to describe phenomena best understood in more complex ways, he placed educational phenomena along continua in his attempt to mix aspects of naturalistic research and experimental design throughout other studies in his career (Dewey, 1904, 1930).

Imitating these approaches, I designed a typology that places university-based professional development contexts along two axes (continua) in an attempt to determine how certain aspects of professional development impact teachers, including teachers’ views on the nature of science (VNOS). The combination of these two continua (Figure 4) was to be used to identify professional development contexts or scenarios in an attempt to generate a theory about how a professional development context impacts teachers’ understandings of the nature of science.

In the subsequent section, the ends of each continuum are delineated using the science education literature (Continuum Y) and the educational leadership literature (Continuum X). These a priori constructs have been used to craft instruments and protocols and have served as codes to analyze data. Please note that these a priori
constructs and codes are explicitly presented and will be frequently referred to throughout the rest of the dissertation.

Both qualitative and quantitative methodologies were used to categorize the seven university-based workshops for science teachers along the X-continuum, *professional development providers’ views of teacher as professionals*, and the Y-continuum, *pedagogical orientations of professional development*, and to gauge how and if teachers’ views of the nature of science change as a function of attending a summer course. These two continua provide a framework--or “*a priori specification of constructs*” (Eisenhardt, 1989) for this study of professional development contexts.

**Continuum X (Figure 2), professional development providers’ views of teachers as professionals**, is rooted in the understanding that educators have “deep structures of beliefs” that are bound to impact educational programs (Boyd, 2003). Little (1993) asserts that how a professional development provider views teachers--whether as professionals or technicians-- is likely to determine the organization and presentation of professional development.

![Figure 2 – Continuum X](image)

By engaging teachers as *professionals*, professional developers:

P1⁵) Motivate learning and improve instruction by recognizing that teachers have specific strengths (Darling-Hammond & McLaughlin, 1995). Specifically, professional

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⁵ P1, P2, and P3 are *a priori* codes for “Teacher as Professional.”
developers who are content experts make themselves *accessible to teachers* and *engage them as peers* by recognizing their instructional expertise (Joyce & Showers, 2002; Tillema & Imants, 1995, p. 147).

**P2)** Empower teachers to take instructional risks and to help make the school culture more collaborative and improvement-oriented (Fullan, 2001; Hawley & Valli, 1999; Little, 1993; Smylie & Weaver-Hart, 1999). Professional developers can encourage teachers to assume these new roles by promoting *collaborative* and *flexible* learning environments (Hargreaves, 1994; Joyce & Showers, 2002).

**P3)** Acknowledge that teachers have unique kinds of knowledge and skills (Darling-Hammond & McLaughlin, 1995; Shulman, 1987) that can be used in planning and further developed through professional learning experiences (Loucks-Horsley et al., 1998). Professional developers who recognize these skills and knowledge encourage teachers to *reflect on their professional practice* (Joyce & Showers, 2002; Schön, 1991).

Professional development providers that view teachers as *technicians* assert that:

**T1**6) The teacher’s role in professional development needs to be limited because of a lack of required skills and knowledge (Hawley & Valli, 1999; Little, 1993). Professional development environments guided by this view have a tendency to clearly delineate roles: The professional developer provides the information and the teacher adopts it (Tillema & Imants, 1995, p. 147). *Time use* in these environments is an “objective variable, an instrumental, organizational condition that can be managerially manipulated in order to foster the implementation of educational changes whose purpose and desirability have been determined elsewhere” (Hargreaves, 1994, p. 95; Schön, 1991).

6 T-1 and T-2 are a priori codes for Teacher as Technician
T2) Teachers are limited in their ability to self-assess their subject matter knowledge and pedagogical content knowledge, implying that administrators and professional development providers are better suited for defining what teachers need to learn in order to close the gap between school goals and school performance while simultaneously protecting teachers from unnecessary and unproductive involvement, unfair expectations, and burnout (Borko & Putnam, 1995; Hawley & Valli, 1999). In these professional development environments, prespecified skills and content are taught and resources are presented to teachers, who may use this information because they find it interesting or because there is some type of coercion (Joyce & Showers, 2002; Tillema & Imants, 1995, p. 146).

Teachers and other educators have often viewed “teacher as technician” models of professional development in a negative light (Grimmet & Mackinnon, 1992; Sparks & Loucks-Horsley, 1990; Tillema & Imants, 1995) because these models are often promoted by state or federal government agencies and implemented by district and school level administrators (Bybee & Loucks-Horsley, 2001; Little, 1993): Historically, many of these programs have rendered teachers invisible (Smyth, 1995). However, if implemented in a way that does not alienate teachers, these top-down models of professional development have the potential to have a lasting impact on teachers’ “behavioral repertoires” (Joyce & Showers, 2002; Tillema & Imants, 1995, p. 136), even affecting attitudes towards and practices of scientific inquiry (Supovitz, Mayer, & Kahle, 2000).

Continuum Y (Figure 3), conceptually-based/substantive to experience-based/syntactic models of professional development, is based upon an assumption that
pedagogical orientations in science teacher professional development should engage teachers at *substantive* levels with scientific concepts, principles, laws, and models of knowledge, and at *syntactic* levels with norms, arguments, paradigms, and ways of establishing new knowledge in a scientific field (Schwab, 1964). Schwab intended that this distinction could be used to delineate the “conceptual and methodological features of a discipline,” an ambition with implications for curriculum and teacher professional development (Carlsen, 1991).

*Conceptually-based/substantive* models of professional development exhibit the following characteristics: 1) They give high priority to the clear delivery of scientific concepts, 2) Their format focuses primarily on scientific concepts and subject matter, 3) They attempt to establish a relationship between the information presented and the teachers’ own understanding and use of scientific concepts, and 4) The evaluation of their outcomes places an emphasis on teachers’ ability to “map” the scientific concepts learned in the course (Schwab, 1964; Tillema & Imants, 1995).

*Conceptually-based/substantive* models of professional development are not always synonymous with more didactic pedagogical methods-- This process of “formulating and conveying knowledge” can occur in many different pedagogical approaches. To bring clarity to the definition, Schwab elucidated the term “substantive” by giving examples of conceptually based orientations in several different settings:

*Thus we formulate and convey some of the knowledge we discover about the body in terms of organs and functions; we formulate and communicate our knowledge of atomic structure in terms of a concept of particles and waves; we formulate some of our knowledge of human personality in terms of psychic organs and their functions and other portions of it in terms of interpersonal relations. In each science . . . such conceptual structures prevail . . . Let us call this set of problems the problem of the substantive structures (Schwab, 1964, pgs. 12 - 13).*
Much of the current professional development literature suggests that adult learners in the sciences need to understand ways of establishing new knowledge in a scientific field (for example, see Loucks-Horsley et al., 1998). Professional developers utilizing an experience-based/syntactic model 1) View the instructor as a facilitator who invites adult learners to exchange and discuss ideas that they have encountered in scientific practice, 2) Focus on sharing experiences and ideas derived from scientific practice, 3) Allow adult learners to guide the direction of the instruction base, and 4) Provide opportunities for teachers to acquire in-depth knowledge of a discipline (Loucks-Horsley et al., 1998; Schwab, 1964; Tillema & Imants, 1995).

Figure 3 – Continuum Y

Simultaneously, experience-based/syntactic models of professional development help define canons of evidence within scientific disciplines, and demonstrate how well those canons can be applied within a classroom. Unlike experiential learning models of professional development that promote “activities for activity sake,” experience-based/syntactic models of professional development intend to generate and establish new knowledge claims:
There is then the problem of determining for each discipline what it does by way of discovery and proof, what criteria it uses for measuring the quality of its data, how strictly it can apply canons of evidence, and in general, of determining the route or pathway by which the discipline moves from its raw data through a longer or shorter process of interpretation to its conclusion (Schwab, 1964, p. 14).

The Evolution of a Third Dimension

Schwab (1964) organized the “general problem of the structure of the (scientific) disciplines” into three components. Beyond substantive conceptual structures and the syntax of each discipline he also identified the organization of the disciplines: how many there are; what they are; and how they relate to one another. Substantive and syntactic structures alone do not provide a complete description of how scientific knowledge is presented in instruction, but they have been useful in the development of educational theories, such as PCK. Baseline data on instructional settings must also be collected, and the interrelationships between science content and context should also be examined (Carlsen, 1991, p. 132). Ultimately, “the researcher of subject-matter pragmatics is faced with the difficult task of choosing an imperfect but serviceable definition of the context of instruction” (p. 133). The present research design originally attempted to deal with these potential shortcomings by collecting and interpreting data on science teaching using multiple definitions of context and by conducting a multiple-level analysis. “By asking related research questions at different levels of analysis, one is potentially better able to understand the generalizability of findings” (p. 133).

Although attentiveness to issues of context and the organization of the subject matters is given, this study capitalizes on contextual similarities in workshop formats in order to better understand other issues. And even though this third dimension has been
an integral part throughout the research design, data collection, and data analysis, some of the discipline specific findings have not been further explored and disclosed in this study in an attempt to preserve the anonymity of the research participants of this study.

Figure 4 – University-Based Professional Development Scenarios for Science Education Workshops
In an evaluation study, the relevant stakeholders need to be identified from the outset. These stakeholders, who are commonly the institutions, groups, individual persons and publishing houses associated with the problem situation being evaluated, should have some say in the design of the evaluation, the data being collected, the analysis of the evidence, and the interpretation of the findings (Keeves, 1998, pgs. 1142 - 1143).

Defining the Context and Specifying the Population

As stated previously, the National Aeronautics Space Administration (NASA) and the National Science Foundation (NSF) have both become increasingly interested in the evaluation of the progress and effectiveness of educational projects they fund (NASA, 2004; Sharp & Frechtling, 1997). These organizations usually conduct evaluations for two fundamental reasons: To gain direction for improving projects as they are developing (formative evaluation), and to determine projects’ effectiveness after they have had time to produce results (summative evaluation) (Sharp & Frechtling, 1997).

In September of 2003 a NASA Space Grant Consortium hired me to evaluate their workshops for science educators. Each summer this organization financially and logistically supports multiple one-week courses for secondary science teachers. Teachers enroll in two-credit, graduate-level workshops from a variety of locations and contexts. During each one-week workshop, teachers interact with university scientists from various colleges and centers for 40 – 50 hours.

Although this venue of professional development does not intend to establish long-term relationships between university scientists and secondary science teachers, the teachers do have the opportunity to establish temporary residence at the university, when they are surrounded and supported by colleagues (National Research Council, 1996a;
National Research Council: Committee on Science and Mathematics Teacher Preparation, 2001). The one-week workshops are intended to support the National Science Education Standards (National Research Council, 1996a): Teachers of science are “professionals responsible for their own professional development and for the maintenance of the teaching profession” (p. 55), and they should have the opportunity for “structured reflection on their teaching practice with colleagues, for collaborative curriculum planning, and for active participation in professional teaching and scientific networks” (p. 58). “Such resources include access to formal… courses that allow them to keep abreast of current science” (p. 70). “The strongest professional development programs result from collaborations among teachers (and) developers, such as . . . university faculty, science coordinators, and teachers… Such collaborations increase coherence, and they bring a wide variety of expertise and resources to bear on a set of common goals that are directly connected to the needs of teachers” (p. 71).

Theoretical, Not Random Sampling

The workshop instructors and coordinators reported that the information received through Likert-scale and open-ended surveys from previous years’ evaluations did not provide adequate information to improve subsequent planning of these content specific workshops, and therefore part of the evaluation process was to improve upon the existing questionnaire so that the teacher feedback was more meaningful to the workshop instructors.

Evaluations are “typically derived from the stated goals of the program or activity . . . (assuming) of course, that explicit student learning goals were identified when the program or activity was planned” (Guskey, 2000, pgs. 210 - 211). However, in order to
follow Guskey’s recommended sequence for program evaluation, my role would have to be changed from a summative to a formative evaluator. Due to the objectives of the evaluation, time constraints, financial limitations, and programmatic parameters, this modification was not possible: Neither the instructors nor I had time or resources to explicitly define workshop goals, rework the curriculum around these goals, and evaluate the workshops based upon these goals prior to the 2004 workshops.

These same constraints that curbed the formative evaluation process enabled me to maintain a naturalistic context ideal for theory building (Strauss & Corbin, 1998). The workshops were also bounded by a number of important features (duration, general format, teacher recruitment and admission, location, number of participants, etc.), providing the structure required when attempting to build theory through case study research (Creswell, 1998; Eisenhardt, 1989; Krathwohl, 1997; Yin, 2003) and making them a unique dataset for comparative research on science teacher professional development. Specifically, each workshop:

- Has similar attendance – ~ 12 secondary science teachers
- Lasts 5 days and approximately 45 hours of instructional time
- Is taught by (a) Ph.D. level scientist(s)
- Takes place on the same university campus
- Optionally conveys two graduate credits
- Is coordinated by the same NASA affiliate
- Uses common recruitment, application, and acceptance processes
- Undergoes a similar evaluation process

The similarities between workshops offer elements of a quasi-experimental design, and these bounded features are crucial in defining the cases from which the research sample is drawn. The predetermined case selection also shared many similarities with hypothesis-testing research (Eisenhardt, 1989; Yin, 2003): Selection of appropriate cases helps limit extraneous variation and helps to define the limits for
readers to “generalize” the findings (Eisenhardt, 1989, p. 537). Even though teachers are selected to attend the workshops through an application process, the population applying to the workshops is self-selecting, a common feature of a quasi-controlled environment (Trochim, 2002b).

Building theories from case study research relies on theoretical sampling, “sampling on the basis of emerging concepts, with the goal of exploring the dimensional range of varied conditions along which the properties of concepts vary” (Strauss & Corbin, 1998, p. 73). This approach is in line with Eisenhardt’s statement that cases “may be chosen to fill theoretical categories and provide examples of polar types . . . The goal of theoretical sampling is to choose cases which are likely to replicate or extend the emergent theory” (Eisenhardt, 1989, p. 537). Case selection with this purpose should involve choosing entities with predominantly similar features experiencing similar events, increasing the potential to replicate findings and the potential to strengthen theory (Eisenhardt, 1989; Harris & Sutton, 1986; Yin, 2003).
The Purpose Revisited After Defining the Context:

Now that the context has been described, we will revisit the twofold purpose of this study. My original purpose as an evaluator was to provide the workshop coordinators and instructors with information about how they could improve workshops in subsequent summers.

The driving research question for my dissertation evolved during the planning of this evaluation: In September of 2003, cognizant of both my limited experience with the workshops and the potential shortcomings of the data, I “open coded” (Strauss & Corbin, 1998) the 91 teacher responses to open-ended questionnaires from the previous summer’s seven workshops, which simply asked: “What did you like BEST about this program?” and “What suggestions do you have to improve this program?” My rationale behind this approach was that researchers who have not become immersed in a study might bring a more objective eye to the evidence (Eisenhardt, 1989). Six categories emerged, which are presented in summary form in Table 3. With this approach, I began the integration of social science research techniques into the evaluative process.

Table 3: Open Codes for 2003 Workshop Evaluations

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>QI</td>
<td>Quality of Instructors</td>
</tr>
<tr>
<td>QC</td>
<td>Quality of Content</td>
</tr>
<tr>
<td>QP</td>
<td>Quality of Pedagogy</td>
</tr>
<tr>
<td>OCA</td>
<td>Organization and Coordination of Accommodations</td>
</tr>
<tr>
<td>OCT</td>
<td>Organization and Coordination of Time</td>
</tr>
<tr>
<td>M</td>
<td>Marketing (also Non-Academic)</td>
</tr>
</tbody>
</table>

The two dominant categories, as determined by frequency of responses, were Quality of Instructors and Quality of Pedagogy. The teachers reported that the instructors
utilized a wide variety of pedagogical and instructional approaches to present content. For the workshop coordinators and me, this raised the question, “How do different workshop contexts impact teacher outcomes?”

As the study progressed, it was clear that the bounded contexts of the seven workshops would produce some common outcomes, so I sought to identify an outcome that would be experienced differently by teachers in each of the workshops. As I discussed in Chapter One, both the literature and educational research clearly identify the importance of helping teachers develop and deliver informed views of the nature of science as a central goal for K – 12 science education (American Association for the Advancement of Science, 1993; Lederman et al., 2002; National Research Council, 1996a), and so “teacher outcomes” was eventually specified as “teachers’ understanding of the nature of science,” and the question was reworded to read, “How do different workshop scenarios or contexts impact teachers’ understanding of the nature of science?”
Chapter 3 – Crafting Instruments and Protocols

The decisions which are based on the findings of the evaluation are largely the prerogative of the funding bodies, although a range of policy options might be advanced after consultations with the stakeholders. However, there is more information available in most well-designed evaluation studies in science education than is of interest to funding bodies. This information sometimes includes instruments that have a potential use outside the study for which they were designed, and data that are available for further analysis. Also, identified relationships and the examination of processes operating under particular conditions can have a generality beyond the specific situations” (Keeves, 1998, pgs. 1142 - 1143).

Multiple Data Collection Methods and Multiple Investigators

New methods of data collection beyond the existing summative and open-ended questionnaires were required to answer these research questions and to develop theory through case study design (Eisenhardt, 1989; Yin, 2003). If my research question had asked, “What impacts do different workshops have on teachers’ understanding of the nature of science?” the question might have been addressed through a survey and analysis of data (Yin, 2003). “But if you need to know ‘how’ or ‘why’ the program had worked (or not), you (should) lean toward a case study or a field experiment” (Yin, 2003, p. 7).

Because the workshops were bounded by time, the data collection methods needed to be designed in a way that ensured that enough description was recorded and data collected so that theory building could occur. To achieve this objective it was necessary to collect multiple forms of data through various methods: A workshop context can be studied through interviews, observation, curriculum text, and performance evaluations, all commonly employed in an embedded case study such as this evaluative research, which involves a single program evaluation with several embedded units (Yin,
An overview of the tentative multiple data collection methods are available in Table 4.

Table 4: Multiple Data Collection Methods

<table>
<thead>
<tr>
<th>Method</th>
<th>Time Frame</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaluation Questionnaire</td>
<td>Summative – given on-line at the end of the workshops</td>
<td>Used several existing questionnaires (Conferences and Institutes, 2003; Horizon Research, 2000; Toh, 1996), Five constructs that apply to all seven workshops were identified.</td>
</tr>
<tr>
<td>In class observations</td>
<td>Ongoing – Full time</td>
<td>Two to three observers were placed in each workshop.</td>
</tr>
<tr>
<td>Interviews with Instructors</td>
<td>Summative – conducted interviews after workshops</td>
<td>Interviews were a part of the iterative process, focusing on Dimension X, Dimension Y, and VNOS.</td>
</tr>
<tr>
<td>Video tape</td>
<td>Ongoing</td>
<td>Approximately 14 hours of video were collected in each workshop. Used to verify observations.</td>
</tr>
<tr>
<td>Changes in the Views of the Nature of Science</td>
<td>Summative – given on-line at the end of the workshops</td>
<td>NOS – Used Views on the Nature of Science Instruments (Lederman et al., 2002).</td>
</tr>
</tbody>
</table>

Questionnaire

Using several existing questionnaires, including Horizon Research’s Local Systemic Change through Teacher Enhancement Professional Development Observation Protocol (Horizon Research, 2000), an institutionally administered workshop evaluation questionnaire (Conferences and Institutes, 2003), and the Determinates of Teacher Professionalism instrument (Toh, 1996), the workshop coordinators and I identified five general categories of interest that applied to all seven workshops. Embedded in these categories were questions used to define the a priori constructs. The five constructs included:

1. Design (of the Professional Development Session)
2. Implementation
3. Science Content
4. Exploring Pedagogical and Instructional Materials
5. Culture
Approximately 75% of the instrument is directly from the Horizon Research questionnaire. After revisions were made, Active Server Pages were created ([http://ei.ed.psu.edu/space/](http://ei.ed.psu.edu/space/)) and the .asp documents were linked with a database so that the data could be efficiently collected (Appendix A).

Both written and verbal instructions were given to the teachers before they filled out the questionnaire. The lead instructors of each workshop allocated a minimum of 35 minutes to the completion of this questionnaire and the questionnaires were administered on the last day (Friday) in all the workshops. During the administration of each evaluation a class set of the paper version was on hand, just in case the computers or the servers were down. The paper version was used in the first workshop because the web page was not yet operational. The information gathered on the paper questionnaire was later entered into the database using the web survey, and the information uploaded into the database was rechecked with the paper surveys to ensure reliability.

Within this questionnaire the limits of the construct defined along Dimension X, professional development providers’ views of teachers as professionals, were differentiated through the combination of “sub-constructs” (Jick, 1979). First, section II part V of the questionnaire (Appendix A) gauged whether the teachers who attended the workshops were treated as professionals. The eight Rating Key Indicators were measured on a five-point Likert scale. A rating of one was indicative of professional developers treating teachers as technicians and a rating of five was indicative of the

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7 Both the Questionnaire and VNOS Questionnaire were administered in at the same time and therefore the instructions for these two sections might appear to be redundant.
professional developers treating teachers as professionals. The a priori codes on which these sub-constructs were based are presented below\textsuperscript{8}.

1. Active participation of all was encouraged and valued. (T-1 – P-1)
2. There was a climate of respect for participants’ experiences, ideas, and contributions. (T-1,2 – P-1,3)
3. Interactions reflected collegial working relationships among participants. (T-1 – P-2)
4. Interactions reflected collaborative working relationships between facilitator(s) and participants. (T-1,2 – P-2,3)
5. Participants were encouraged to generate ideas, questions, conjectures, and propositions. (T-1,2 – P-1,3)
6. Participants demonstrated a willingness to share ideas and take intellectual risks. (T-1 – P-2)
7. Intellectual rigor, constructive criticism, and the challenging of ideas were evident. (T-,2 – P-3)
8. Respect for diversity within the context of the workshop. (T-1 – P-2)

Continuum X, Professional development providers’ views of teachers as professionals are based on the premise that the distinctions between professional and technician is value neutral. However, in an effort to preserve the validity of the Horizon questionnaire, the original items could only be minimally altered and therefore communicated a negative view of the “teacher as technician” (Grimmet & Mackinnon, 1992; Sparks & Loucks-Horsley, 1990; Tillema & Imants, 1995). Unlike other metrics used to collect data on the X Continuum, the language used in the Horizon items tends to assign a positive value to the “teacher as professional” and a negative value to the “teacher as technician.” Minor alterations were made in this language to minimize the value-leaderness of the original questionnaire, but it should be noted that a priority was placed on maintaining the validity and rigor of the original instrument.

Second, a synthesis rating for Part V had teachers place the “culture” of each workshop along a five-point Likert scale (Appendix A). The rating of one reads,

\textsuperscript{8} The codes were presented in detail in Chapter One.
“Culture of Professional Development workshop NOT at all reflective of best practice professional development.” The rating of five reads, “Culture of Professional Development workshop extremely reflective of best practice professional development.”

The teacher questionnaire was also used to assess Dimension Y, conceptually-based/substantive to experience-based/syntactic models of professional development, the teachers’ perspective about the pedagogical orientation utilized in the workshop. Twelve “rating key indicators,” were assessed using a five-point Likert scale, with the rating of one meaning “not at all” and the rating of five meaning “to a great extent”:

Experience-based/Syntactic models
1. Ways of establishing new knowledge in the field were discussed in the workshop.
2. The workshop emphasized standards of verification specific to the scientific content being presented.
3. Discipline specific strategies of scientific inquiry were presented and used within the context of this workshop.
4. The format of the workshop focused primarily on scientific processes, not scientific concepts.
5. The design of the session incorporated tasks, roles, and interactions consistent with the spirit of scientific investigation.
6. Science was portrayed as a dynamic body of knowledge continually enriched by conjecture, investigation, analysis, and/or proof of justification.
7. Elements of scientific abstraction (symbolic representation, theory building) were included when it was important to do so.

Conceptually-based/Substantive models
1. The workshop placed a high priority on the clear delivery of scientific concepts.
2. The format of the workshop focused primarily on the clear delivery of scientific concepts, not understanding scientific processes.
3. The format of the workshop attempted to establish a relationship between the concepts presented and the teachers’ understanding and use of these concepts.
4. The evaluation placed an emphasis on the teachers’ ability to communicate/express scientific concepts learned in the course.
5. Teachers were intellectually engaged with the scientific concepts presented throughout the workshop.
6. The scientific concepts presented in the workshop were sound and appropriately explored.
7. Discipline specific terms were presented as necessary for effectively formulating and communicating the knowledge and concepts in that scientific field.
The construct defined along Dimension Y (conceptually-based/substantive to experience-based/syntactic models of professional development) was measured several ways. According to the designers of this portion of the Horizon questionnaire, construct validity was established through a team of expert teachers, administrators, and university faculty (Horizon Research, 2000). Although no statistical analysis on the questionnaire has been published regarding construct validity, because of the expertise of this team and the well-regarded reputation of Horizon Research, I proceeded under the assumption that the design of this questionnaire was sound and that its questions were valid.

In Class Observation- Multiple Investigators

In each workshop two to three observers quantitatively recorded the pedagogical approach every fifteen minutes (Appendix B). The observers also wrote a brief descriptive overview of what occurred every hour in the workshops. The observers were six graduate students and two senior undergraduate students in science education who were participating for credit in the workshops.

Based on previous summers’ demographics, the workshop coordinators and I identified two major populations of teachers: 1) neophyte teachers who did not have families and 2) late career teachers whose children were no longer living at home. Although the observers had limited K-12 teaching experience, most were approximately the same age and appeared to have backgrounds similar to the neophyte teacher population. Consequently, the reactive effects of adding one or two observers to each workshop are believed to be minor. The presence of and roles of these observers were explained in detail to the workshop instructors and to the teacher participants prior to the commencement of each workshop.
I attended all of the workshops and collected field notes that related to the pedagogical orientation; two days of each workshop were videotaped to help validate the data collected by the workshop observers. Multiple observers in the data collection process strengthen the internal and external validity of this mixed method study.

<table>
<thead>
<tr>
<th>Table 5: Workshop and Observer Background</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observer</td>
</tr>
<tr>
<td>----------</td>
</tr>
<tr>
<td><strong>Workshop A</strong></td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td><strong>Workshop B</strong></td>
</tr>
<tr>
<td>6</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td><strong>Workshop C</strong></td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td><strong>Workshop D</strong></td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td><strong>Workshop E</strong></td>
</tr>
<tr>
<td>9</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td><strong>Workshop F</strong></td>
</tr>
<tr>
<td>6</td>
</tr>
<tr>
<td>7</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td><strong>Workshop G</strong></td>
</tr>
<tr>
<td>8</td>
</tr>
<tr>
<td>1</td>
</tr>
</tbody>
</table>
The classroom observation form was based upon Magnusson, Krajcik, and Borko’s (1999) framework, which categorizes nine orientations that teachers use while teaching science. These orientations can be described with respect to two elements: the goals of teaching science that a teacher with a particular orientation would have (Table 1 on page 100 of their book chapter), and the typical characteristics of the instruction that would be conducted by a teacher with a particular orientation (Table 2 on page 101 of their book chapter) (Magnusson et al., 1999, p. 97).

To further ensure that the observation task did not have a reactive effect on classroom participation, I constructed an instrument based solely upon Table 2, the characteristics of instruction. Although the goals of a teacher are important, they are not always explicitly stated. Characteristics of instruction, however, are always apparent and observable (Magnusson et al., 1999).

Transforming this descriptive table into a functional instrument was accomplished by borrowing from the structure of Ned Flander’s *Interaction Analysis in the Classroom: A Manual for Observers* (1964). Although Flander’s instrument was designed to assess verbal behavior in a class, its systematic procedures were easily transferred to evaluate pedagogical orientations. Flander’s Interaction Analysis utilized preexisting definitions, or *a priori* constructs, to categorize classroom occurrences. Flanders suggested that after a brief period of time, observers should “decide which category best represents the communication events just completed. He (she) writes this category number down while simultaneously assessing communication in the next period” (p. 2).

Flanders used 10 categories, divided into two subcategories, and required that an observer would understand and memorize each of the categories prior to engaging in
classroom research. The observers were allowed to use only one category for each time interval. Flanders suggests that after the observers memorized the 10 categories, training should begin with audiotapes of classroom interactions. “It is desirable to have a variety of training tapes that provide unusual examples of …patterns” (p. 7). Trainees should be introduced to long uninterrupted sections of tape and discussion of the categorization process should ensue after the completion of these training observations.

Based upon the literature and prior to the observation process I consolidated nine pedagogical orientations (Magnusson et al., 1999) into three categories that were reflective of the Y – continuum: Conceptually-based/Substantive (CS), Experience-based/Syntactic (ES), and Neutral (N). Magnusson et al.’s definitions of academic rigor, didactic, and student conceptions logically corresponded with the literature used to create the conceptual-based/substantive end of the Y- continuum. Their definitions of process, project based, guided inquiry, and independent inquiry logically corresponded with the literature used to create the experienced-based/syntactic end of the Y- continuum. The definitions used to explain the discovery and activity pedagogical orientations do not tend towards either side of the continuum, and the Neutral category was created and defined as “activity for activity sake.”

The three training sessions for participant-observers in my study were designed to test the effectiveness of this classroom observation instrument, created to measure pedagogical orientations (Appendix B). The validity of the instrument would be gauged when the student observers and I compared our data sheets at the end of each training session and measured the inter-rater reliability. This validity was maintained in the actual workshops.
The first training session took place on both April 8th and April 9th 2004 to accommodate differing schedules of the workshop observers. On April 8th, observers 2, 4, 5, 6, 8, and 9 met from 2:30 to 4:30 pm. Observer 8 had to leave at 4:10 pm, and completed the exercise by coming up 30 minutes early for Session 2. On April 9th, 3, 7, and 10 met from 4:30 to 6:30 pm. Outcomes from both days were combined and are listed in Table 7. During the first half-hour of session 1 I introduced the Time-Based Pedagogical Orientation Instrument (Appendix B) and reviewed the Instructions for the

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Observer 10 took part in all the trainings but dropped out of the study prior to the workshops.
use of the instrument (Appendix C), which includes definitions for each of the nine pedagogical orientations. The workshop observers and I then viewed a 30-minute video of a previous year’s workshops and collectively discussed and identified the pedagogical orientations. The 15 minute observation intervals that were to be used in the summer workshops were changed to three minute observation intervals during the training sessions in order to insure that the observers had more interactions with the instrument during the limited training times. I concluded the first session by showing 57 minutes of footage from a 2003 workshop, allowing the observers to made 19 3-minute observations.

The inter-rater reliability was calculated using percentages. 8 out of the 19 intervals had an inter-rater reliability of 100% (Table 7).

<table>
<thead>
<tr>
<th>Interval</th>
<th>IRR/ # of Observers</th>
<th>Orientation</th>
<th># of Observers</th>
<th>Orientation</th>
<th># of Observers</th>
<th>Orientation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9 – 100%</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>6 – 67%</td>
<td>2</td>
<td>3 – 33%</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>9 – 100%</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>4 – 44%</td>
<td>3</td>
<td>3 – 33%</td>
<td>2</td>
<td>2 – 22%</td>
<td>5</td>
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<tr>
<td>5</td>
<td>6 – 67%</td>
<td>2</td>
<td>3 – 33%</td>
<td>3</td>
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<tr>
<td>6</td>
<td>9 – 100%</td>
<td>3</td>
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<td></td>
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<tr>
<td>7</td>
<td>6 – 67%</td>
<td>3</td>
<td>3 – 33%</td>
<td>4</td>
<td></td>
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</tr>
<tr>
<td>8</td>
<td>9 – 100%</td>
<td>3</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>5 – 56%</td>
<td>3</td>
<td>3 – 33%</td>
<td>4</td>
<td>1 – 11%</td>
<td>5</td>
</tr>
<tr>
<td>10</td>
<td>9 – 100%</td>
<td>3</td>
<td></td>
<td></td>
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<tr>
<td>11</td>
<td>9 – 100%</td>
<td>3</td>
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<tr>
<td>12</td>
<td>9 – 100%</td>
<td>3</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>13</td>
<td>9 – 100%</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>14</td>
<td>5 – 56%</td>
<td>3</td>
<td>4 – 44%</td>
<td>4</td>
<td></td>
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</tr>
<tr>
<td>15</td>
<td>5 – 56%</td>
<td>5</td>
<td>4 – 44%</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>4 – 44%</td>
<td>2</td>
<td>3 – 33%</td>
<td>5</td>
<td>2(1) –11%</td>
<td>3/9</td>
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<tr>
<td>17</td>
<td>6 – 67%</td>
<td>3</td>
<td>2 – 22%</td>
<td>5</td>
<td>1 – 11%</td>
<td>8</td>
</tr>
<tr>
<td>18</td>
<td>5 – 56%</td>
<td>3</td>
<td>3 – 33%</td>
<td>4</td>
<td>1 – 11%</td>
<td>8</td>
</tr>
<tr>
<td>19</td>
<td>4 – 44%</td>
<td>3</td>
<td>4 – 44%</td>
<td>4</td>
<td>1 – 11%</td>
<td>8</td>
</tr>
</tbody>
</table>
The pedagogical orientation for all 8 intervals was categorized as “didactic.” Although these 8 time-intervals occurred in the same workshop, four different instructors were represented. Of the remaining intervals, four had an IRR of 67%, four had an IRR of 56%, and three had an IRR of 44%.

Upon leaving the first session, the observers were asked to study both the Instructions to the Time-Based Pedagogical Orientation Instrument (Appendix C) and the Time-Based Pedagogical Orientation Instrument (Appendix B) so that they would become familiar with the protocol before the second training session.

The second session (Tables 8 - 10) took place on April 22, 2004 from 6:45 – 10:00 p.m., and all of the observers were able to attend. During the first hour we once again went over the Instructions to the Time-Based Pedagogical Orientation Instrument (Appendix C) and reviewed the Time-Based Pedagogical Orientation Instrument (Appendix B). Based upon the data gathered during session one and feedback given from the observers, minor changes had been made to both the Time-Based Pedagogical Orientation Instrument (Appendix B) and the Instructions for the use of the Time-Based Pedagogical Orientation Instrument (Appendix C). These changes included changing the instructions to include a specific observation interval\(^{10}\) and clarifying the definitions of academic rigor and student conceptions.

The changes in both the instructions and the definitions enabled the observers to achieve a higher IRR for session two. The results from session one were handed back to the observers and we watched all the time intervals that had an IRR of less than 100%. During this time I justified what I perceived to be the most accurate pedagogical

\(^{10}\) Changed from “an overview of the last 1 – 2 minutes” to “an overview of the last two minutes.”
orientation\textsuperscript{11}, and then the observers and I discussed any differences in choice of orientation until there was complete consensus for the decisions and clarity for the definition.

For the remainder of session two, the observers viewed and categorized three segments of video. The first segment of video (Table 8) consisted of 12 minutes of footage from a geological science undergraduate course. My purpose for choosing this segment of video was to verify that the IRR for the didactic pedagogical orientation would remain high, even within a different context. Each of the four time intervals had an IRR of 100%.

Table 8 – Training Session 2: 12 minutes of Undergraduate Geology Class

<table>
<thead>
<tr>
<th>Interval</th>
<th># of Observers</th>
<th>Orientation</th>
<th># of Observers</th>
<th>Orientation</th>
<th># of Observers</th>
<th>Orientation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9 – 100%</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>9 – 100%</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>9 – 100%</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>9 – 100%</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The second segment (Table 9) of video consisted of 18 minutes of footage from the 2003 Workshop A. My reasoning for selecting this segment of video was to see if the earlier discussion viewed in training session 1, during which we attempted to resolve our categorizing discrepancies from session one, had helped resolve some of the low IRR for intervals 14 - 19. The 18-minute segment from session one and this 18-minute session selected for session two were of the same instructor utilizing a variety of pedagogical

\textsuperscript{11} Except for two time intervals, my perception agreed with the majority of observations made during Session One.
approaches. However, it should also be noted that the quality of the segment of video selected for session two was poor due to multiple cuts and low volume.

The IRR outcomes were quite similar to the IRR outcomes of intervals 14-19 from session one. During the discussion after this 18-minute observation, the observers indicated that the video quality inhibited their ability to accurately categorize the pedagogical approach of this video clip. The observers said that this segment of video did not allow them to understand what was occurring in the class due to the multiple cuts and low volume. These comments led me to conclude that the low IRR was an outcome of the video quality, not of the observer’s training.

The third segment of video (Table 10) consisted of 24 minutes of footage from an undergraduate chemistry course. My purpose for choosing this segment of video was to verify that observers could differentiate between pedagogical orientations 2 (academic rigor) and 5 (activity driven). The IRR for the portions depicting “academic rigor” were 89%. Observer 6, who chose “activity driven,” indicated that she was not clear on whether the students understood the concept that the laboratory experiment was based upon.

<table>
<thead>
<tr>
<th>Interval</th>
<th># of Observers</th>
<th>Orientation</th>
<th># of Observers</th>
<th>Orientation</th>
<th># of Observers</th>
<th>Orientation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9 – 100%</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>5 – 56%</td>
<td>3</td>
<td>2 – 22%</td>
<td>5</td>
<td>2 – 22%</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>5 – 56%</td>
<td>5</td>
<td>2 – 22%</td>
<td>5</td>
<td>2(1) –11%</td>
<td>7/9</td>
</tr>
<tr>
<td>4</td>
<td>6 – 67%</td>
<td>4</td>
<td>3(1) –11%</td>
<td>3/8/5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>4 – 44%</td>
<td>5</td>
<td>3 – 33%</td>
<td>7</td>
<td>2 – 22%</td>
<td>8</td>
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<tr>
<td>6</td>
<td>3 – 33%</td>
<td>7</td>
<td>2(2) –22%</td>
<td>4/8</td>
<td>2(1) –11%</td>
<td>3/5</td>
</tr>
</tbody>
</table>

The third segment of video (Table 10) consisted of 24 minutes of footage from an undergraduate chemistry course. My purpose for choosing this segment of video was to verify that observers could differentiate between pedagogical orientations 2 (academic rigor) and 5 (activity driven). The IRR for the portions depicting “academic rigor” were 89%. Observer 6, who chose “activity driven,” indicated that she was not clear on whether the students understood the concept that the laboratory experiment was based upon.
Initial data analysis indicated that eight of the nine observers were consistent in their choice of pedagogical orientations. These eight observers tended to choose the consensus category at a consistent rate. Observer 6 appeared to choose the consensus category at a consistently lower rate. Sessions one and two have led me to conclude that the observers using this instrument in the summer workshops would be able to accurately categorize pedagogical orientations 2 (academic rigor), 3 (didactic), 4 (student conceptions), and 5 (activity driven)\textsuperscript{12}.

Unfortunately, due to limited video footage, I had difficulty validating that the student observers can categorize 1 (process), 6 (discovery learning), 7 (project-based science), 8 (guided inquiry), and 9 (independent inquiry). Accurate categorization of these orientations might be due to the extended periods of time that they require: The definitions of these three categories suggest that they are processes requiring multiple stages and ample time. However, throughout these training sessions the observers indicated that they understood the nuances captured in the definitions of conceptually-based/substantive (CS), experience-based/syntactic (ES), and the neutral (N) pedagogical orientations.

\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|c|c|}
\hline
Interval & # of Observers & Orientation & # of Observers & Orientation \\
\hline
1 & 9 – 100\% & 3 & & \\
2 & 9 – 100\% & 3 & & \\
3 & 9 – 100\% & 3 & & \\
4 & 8 – 89\% & 2 & 1 – 11\% & 5 \\
5 & 8 – 89\% & 2 & 1 – 11\% & 5 \\
6 & 8 – 89\% & 2 & 1 – 11\% & 5 \\
7 & 8 – 89\% & 2 & 1 – 11\% & 5 \\
8 & 8 – 89\% & 2 & 1 – 11\% & 5 \\
\hline
\end{tabular}
\caption{Session 2: 24 minutes of Undergraduate Chemistry Class}
\end{table}

\textsuperscript{12} The success of classifying these pedagogical orientations strengthens the quantification process of Dimension Y in regards to the observation protocol.
orientations. For example, during activity-based or experiential intervals that did not generate and establish new knowledge claims, the observers chose neutral (N) instead of experience-based/syntactic (ES). Similarly, observers were able to identify intervals that generated and established new knowledge claims as experience-based/syntactic (ES) and intervals that formulated and conveyed knowledge as conceptually-based/substantive (CS).

During session three we reviewed the outcomes of session two and discussed in depth the characteristics of these other categories. This session was intended to be a refresher course, and in order to avoid observer drift I met with the observers in small groups approximately two weeks before their respective workshops. I met with observers 2, 3, 4, 5, and 6 on June 16, 2004-- six days before the beginning of Observers 2 and 3’s workshop, and 13 days before Observers 4, 5, and 6’s workshop. Observers 7, 8, and 9 attended their third training on June 30, 2004-- 11 days prior to observers’ 7 and 8 workshops, and 18 days prior to observer 9’s workshop. Observers 3 and 6 each attended training session 3 and observed a workshop earlier in the summer and were not required to attend the refresher session for their second workshop.

During each 40-hour workshop, 92 – 111 (mean 102) “pedagogy at the moment” observations were made. The number of observers present determined how the score was calculated. If all the observers agreed on a consolidated category for an interval, each conceptual-based/substantive observation was scored as “+1”, each experienced-based/syntactic observation was scored at “−1”, and each neutral observation was scored as “0.” In a workshop with three observers, if for a given interval two of the observers recorded didactic and one
recorded *academic rigor*, each individual observation would be scored as +1
because the two pedagogical orientations fall into the conceptual-
based/substantive category, each score would be multiplied by 1/3, and the three
scores would be added together for an overall score of +1. If one observer
recorded *activity* and the other two observers recorded *academic rigor*, each
observation would be individually scored and multiplied by 1/3, so the sum total
would equal +2/3. Neutral observations were then scored separately and recorded
so that the reader could compare the amount of time spent on *activity* and
*discovery* pedagogical orientations. Similarly, in a workshop with two
observers, if for a given interval one of the observers recorded *didactic* and one
recorded *academic rigor*, each individual observation would be scored as +1
because the two pedagogical orientations fall into the conceptual-
based/substantive category, and then each score would be multiplied by 1/2, and
the two scores would be added together for an overall score of +1.

Because the number of observers varied between workshops, the inter-rater
reliability was also calculated based on a point system. For example, if three observers
were in a workshop and all recorded the same pedagogical orientation for a particular
interval, one point would be scored. If two of the observers agreed and one observer
disagreed, 2/3 of a point would be scored. If each of the observers recorded a different
pedagogical orientation, 1/3 of a point would be scored.

The scores for both the pedagogical orientation and the inter-rater reliability were
totaled and divided by the total number of observation intervals to calculate a percentage.
These are recorded on Table 17 (page 110).
Interviews with Instructors

Using extant strategies (Janesick, 2004; Rossman & Rallis, 2003), an interview protocol was created to gather information pertaining to the lead workshop instructor’s views of Dimension X, Dimension Y, and the NOS (Appendix D). The seven interviews were digitally recorded and transcribed.

The interview protocol presented in my proposal was designed to take approximately 40 minutes and stated that it was “to be administered approximately two weeks to one month after the workshop.” I realized that this schedule was not plausible once the workshops started due to summer scheduling conflicts experienced by both the instructors and me. Toward the end of the summer the NASA subsidiary asked me to meet with each of the instructors to review their workshop’s evaluation, so I determined that it would be better to conduct my interview protocol during these meetings. The evaluation overview required approximately 40 minutes, and, while scheduling appointments with the instructors, I realized that the interview process would have to be limited to 15 – 20 minutes to ensure that the total meeting time was less than one hour: Most of the instructors indicated in our correspondence that they were very busy and could not spend too much time going over the evaluation.

When the interview process began, I had observed all seven workshops and conducted an initial data analysis of the surveys. A better understanding of the workshops coupled with the interview time constraints caused me to rewrite the interview protocol. Questions 1 – 2 were specifically written to explore the instructors’ views about teachers as professionals/technicians and were intended to assist in the placement of the instructors’ perspectives along the technician – professional continuum (Table 11).
Questions 3 and 4 were written to explore the instructors’ pedagogical and curriculum approaches and to see if/how these approaches were limited by the current structure of the workshop. The instructors’ response to these questions was coded and the results of this analysis were correlated to the other methods that examined the pedagogical approaches within this workshop.

Question 5 and 6 were designed to explore the instructor’s views about the nature of science and how the nature of science is presented to teachers.

<table>
<thead>
<tr>
<th>Table 11-Interview Protocol</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. How do you think the day-to-day work of (science) teachers differs from Ph.D. instructors (scientists) at the university who only have teaching responsibility (no research)?</td>
</tr>
<tr>
<td>2. A teacher calls you and asks you to explain your expectations of the participants who attend your workshop. How would you respond? (Please note if there are differences between your workshops.)</td>
</tr>
<tr>
<td>3. What goals have you established for teachers who attend your workshop? How do you facilitate the teachers in achieving these goals? (Please note if there are differences between your workshops.)</td>
</tr>
<tr>
<td>4. Imagine that the Schreyer Institute calls you, stating that they are impressed by your workshop and they have decided to allocate $20,000 to help you further develop it. You can spend the money any way that you would like. How would you spend it? (Please note if there are differences between your workshops.)</td>
</tr>
<tr>
<td>5. Please look at these questions from the Views of the Nature of Science Survey that I administered to the teachers at the end of the workshop. (Questions 1, 5, and 8 – these are the questions that teachers responded most often to) If a teacher answered “yes” to having experienced change in their understanding of the NOS in your workshop, what about your workshop (what aspect of your workshop) do you believe caused this change?</td>
</tr>
</tbody>
</table>
| 6. There is a big debate among science education researchers. Some evidence indicates inservice teachers need to be taught the nature of science explicitly: for example, there needs to be an explicit curriculum that defines science, theory, experiments, or how these processes occur….Others state that scientists learn implicitly about the nature of science by doing science – they are not presented with an explicit curriculum of science – therefore teachers should also learn about science in this way. How would you characterize your workshop: as implicitly or explicitly instructing teachers about the nature of science?
Video tape

Due to limitations placed on this study by my university’s Institutional Review Board (IRB), the video being collected could not be used as an original source of data collection. As stated in the consent forms, the video was only to be used to verify information gathered through the other methodologies, such as observations, archival sources, and interviews. The only way that the IRB would agree to allow me to use video as a source of data collection, rather than data verification, was to place checkboxes in the consent forms that explicitly stated whether the teacher/instructor could or could not be videotaped for research purposes.

The decision not to place these checkboxes in the consent forms was reached after a discussion with the workshop coordinators: We were worried the workshop dynamics would be changed if teachers indicated that they did not want to be videotaped. The consent forms were written to indicate that a video recording would occur in each classroom, but that the purpose of this video was to help in the verification and analysis of the other methodologies. Teacher/Instructors still had the opportunity to notify me if they did not want to be videotaped, but I believe that this approach was more conducive to maintaining a natural classroom setting. None of the teachers indicated that they did not want to be videotaped.

Changes in the Views of the Nature of Science Questionnaire

This questionnaire was generated using both VNOS forms B and C (Lederman et al., 2002). The instrument was designed as an Active Server Page that linked to a database. Each question in the instrument has two parts: First the teacher needs to
indicate whether or not they experienced a change in their views on the NOS. If they check “no,” they go onto the next question. If they check “yes,” they will then proceed to indicate how their VNOS have changed in the accompanying text box.

Both written and verbal instructions were given to the teachers before they filled out the questionnaire. To ensure that the teachers understood the instructions, I visually walked the teachers through each part of the questionnaire using the paper copies. Each of the seven workshop lead instructors allocated approximately 30 minutes to the completion of this questionnaire. The questionnaire was administered in all the workshops on the last day (Friday) at approximately 10:30 am.

Validity and Reliability of Mixed Methods

Yin elucidates on how to design studies that take advantage of “valid inferences from events outside the laboratory while at the same time retaining the goals of knowledge shared with laboratory science” (Yin, 2003, p. ix, from Donald Cambell's preface) by bringing the “concerns of validity and reliability in experimental research design to the design of case study research.” Specifically he delineates how mixing qualitative and quantitative methods can strengthen single or multiple case study research.

Yin presents three “tactics” by which construct validity of an embedded case study can be attained. His first suggestion is to use mixed methods to triangulate and explore the same construct(s). Denzin (1970), Jick (1979), Creswell (Creswell, 2003b), Yin (2003), and Eisenhardt (1989) each offer similar design tips on how to triangulate the data collected through these processes. Yin’s second suggestion requires that the researcher scrupulously collect data and “maintain a chain of evidence,” allowing the
external observer or reader to “follow the derivation of any evidence, ranging from initial research questions to ultimate case study conclusions.” The reader should also be able to connect conclusions to the research question and vice-versa (Yin, 2003, p. 105). The third and final tactic is for the draft of the report to be reviewed by both peers and participants in the case: “The corrections made through this process will enhance the accuracy of the case study” and increase the construct validity (Yin, 2003, p. 159). This process is also known as member checking (Creswell, 1998).

While the external validity of both experimental and quasi-experimental designs rely on “statistical generalization,” the external validity of theory building case studies are dependent on “analytical generalization” (Yin, 2003). In a case study this form of generalization is arrived at by asking if replication logic, the same used in experimental design, verifies a theory’s legitimacy in similar situations. In other words, “can the research design and finding of this study be replicated in different situations?” The answer is yes: While the focus of my study was on the workshop scenarios, diverse constructs were defined, and the use of “between method” triangulation (or triangulation across constructs) helped to establish replication logic (Jick, 1979).

Achieving strong internal validity is the most difficult aspect of an embedded case study because the design intends out to be both explanatory and exploratory. My research question—“How do different workshop scenarios impact teachers’ understanding of the nature of science?”—define workshop scenario as an independent variable and teacher outcome as the dependent variable. This study attempts to establish a causal relationship and therefore the design accounts for potentially “spurious” relationships or confounding variables (Light, Singer, & Willett, 1990; Yin, 2003).
Yin describes two tactics for addressing the issues of internal validity within an explanatory case study design. The first tactic, pattern matching (Trochim, 1989), compares an empirically based pattern with a predicted one. If the patterns match, the empirically derived information can be used to strengthen internal validity. These patterns can also point to rival explanations, or independent variables: If one explanation is going to be valid, then the other independent variable must be identified.

Pattern matching requires that the researcher predict what is going to occur within a study, which is contrary to theory building. Yin cites Trochim (1989) as using pattern matching to improve internal validity, but after further review, Trochim’s (2002b) use of pattern matching usually appears in the context of strengthening construct validity. However, if the researcher is able to find an applicable empirical model on which to map this technique of analysis while shaping the hypotheses, enfolding literature, and reaching closure, this technique could be used to substantiate the internal validity during data analysis.

Yin’s second suggestion for strengthening internal validity in case studies involves explanation building, or analyzing data “by building an explanation about the case” (Yin, 2003, p. 120). As with pattern matching, this process also occurs during data analysis. An explanation of a phenomenon defines the causal links or independent variables in “the previously described use of rival explanations” (Yin, 2003, p. 120). These explanations usually occur in narrative form, build on theoretically significant propositions, and have the potential to yield critical insights into social science theory. The process of explanation building can also allow the researcher to address rival
explanations that could potentially undermine the internal validity of a study (Yin, 2003). In this study I have chosen to use explanation building to strengthen internal validity.

Qualitative and Quantitative Data Combined

The combination of data types can be highly synergistic (Eisenhardt, 1989, p. 538).

Qualitative data enable the researcher to enhance quantitative data by providing information that might not be obtainable through conventional written instruments. Qualitative data can also provide a way for explaining anomalies within quantitative data sets and provide a basis through which meaningful interpretations can be made: Qualitative data can often explain patterns revealed through quantitative data, and alternatively quantitative data has the potential to strengthen theories built primarily through qualitative data (Jick, 1979; Solomon, 1991). Ultimately, quantitative data can strengthen both the internal and external validity of a mixed method study.

As stated earlier in this chapter, six different methodologies were designed to collect this data. Table 12 lists the constructs in the left-most column and the six methodologies in the top row. Different key works indicate whether or not a specific methodology was intended to collect data pertaining to a construct. Due to the naturalistic and/or open-ended nature of some methodologies, the word “potentially” is used. As noted earlier, “verification only” is used for the videotape methodology, indicating that videotape can only be used to verify findings of other methodologies. This was a methodological restriction to protect human subjects.
Table 12 - Evaluation Construction and Data Collection Methodology Convergence

<table>
<thead>
<tr>
<th>Data Collection Methodologies</th>
<th>Questionnaire</th>
<th>Observations</th>
<th>Artifacts-Archival Sources</th>
<th>Interviews with Instructors</th>
<th>Videotape</th>
<th>VNOS Questionnaire</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organization and Coordination</td>
<td>Yes</td>
<td>Potentially</td>
<td>Potentially</td>
<td>Potentially</td>
<td>Verification only</td>
<td>Potentially</td>
</tr>
<tr>
<td>Ongoing Professional Development</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Potentially</td>
<td>Verification only</td>
<td>Potentially</td>
</tr>
<tr>
<td>Workshop Activities</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Verification only</td>
<td>Potentially</td>
</tr>
<tr>
<td>Overall Rating of Session</td>
<td>Yes</td>
<td>Potentially</td>
<td>Potentially</td>
<td>Potentially</td>
<td>Verification only</td>
<td>Potentially</td>
</tr>
<tr>
<td>Design</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Verification only</td>
<td>Potentially</td>
</tr>
<tr>
<td>Implementation</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Verification only</td>
<td>Potentially</td>
</tr>
<tr>
<td>Science Content</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Verification only</td>
<td>Potentially</td>
</tr>
<tr>
<td>Pedagogical Instructional Materials</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Verification only</td>
<td>Potentially</td>
</tr>
<tr>
<td>Culture of the PD Session</td>
<td>Yes</td>
<td>Potentially</td>
<td>Potentially</td>
<td>Yes</td>
<td>Verification only</td>
<td>Potentially</td>
</tr>
<tr>
<td>Capsule Description of the Quality PD</td>
<td>Yes</td>
<td>Potentially</td>
<td>Potentially</td>
<td>Potentially</td>
<td>Verification only</td>
<td>Potentially</td>
</tr>
<tr>
<td>Open-Ended Responses</td>
<td>Yes</td>
<td>Potentially</td>
<td>Potentially</td>
<td>Potentially</td>
<td>Verification only</td>
<td>Potentially</td>
</tr>
</tbody>
</table>
The following table (Table 13) depicts the convergence between the research questions and the methodologies used to collect data.

**Table 13 - Convergence between the research question and the methodologies used to collect data**

<table>
<thead>
<tr>
<th>Data Collection Methodologies ▶ Questions ▼</th>
<th>Question.</th>
<th>Observations</th>
<th>Artifacts - Archival Sources</th>
<th>Interviews with Instructors</th>
<th>Videotape</th>
<th>VNOS Questionnaire</th>
</tr>
</thead>
<tbody>
<tr>
<td>How do different professional development contexts impact teachers' understanding of the NOS?</td>
<td>Yes - Specific Questions</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Verification only</td>
<td>Potentially</td>
</tr>
</tbody>
</table>

The following table (Table 14) depicts the convergence between the *a priori* constructs and the methodologies used to collect data.

**Table 14 - Convergence between the *a priori* constructs and the methodologies used to collect data**

<table>
<thead>
<tr>
<th>Data Collection Methodologies ▶ A Priori Constructs ▼</th>
<th>Questionnaire</th>
<th>Observations</th>
<th>Artifacts - Archival Sources</th>
<th>Interviews with Instructors</th>
<th>Videotape</th>
<th>VNOS Questionnaire</th>
</tr>
</thead>
<tbody>
<tr>
<td>Professional Developers' Views of Teachers – Professional</td>
<td>Yes – section II, Part V, questions 1 – 8 and synthesis</td>
<td>Potentially</td>
<td>Potentially</td>
<td>Yes</td>
<td>Verification only</td>
<td>Potentially</td>
</tr>
<tr>
<td>Professional Developers' Views of Teachers – Technician</td>
<td>Yes – section II, Part V, questions 1 – 8 and synthesis</td>
<td>Potentially</td>
<td>Potentially</td>
<td>Yes</td>
<td>Verification only</td>
<td>Potentially</td>
</tr>
<tr>
<td>Pedagogical Orientations of Professional Development – Substantive - Conceptually Based</td>
<td>Yes – P7, S12, P8, P9, I5, S2, S13</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Verification only</td>
<td>Potentially</td>
</tr>
<tr>
<td>Pedagogical Orientations of Professional Development – Experienced Based / Syntactic</td>
<td>Yes – S3, S9, S10, S11, D1, S5, S7</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Verification only</td>
<td>Potentially</td>
</tr>
<tr>
<td>Subject Matter</td>
<td>Yes –</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Verification only</td>
<td>Potentially</td>
</tr>
</tbody>
</table>
A striking feature of research to build theory from case studies is the frequent overlap of data analysis with data collection . . . While many researchers do not achieve this degree of overlap, most maintain some overlap (Eisenhardt, 1989, p. 538)

Ongoing observations and accompanying in-depth field notes allowed me to construct knowledge of the research environment. The research collection and data analysis are consistent with the original research design described in my proposal. Two days of video were recorded in each of the seven workshops. Over 14 hours of footage for each of the workshops were recorded on sixty-seven 90-minute mini digital videotapes. Multiple observers made an average of 102 15-minute interval observations in each workshop, and these data helped in defining the pedagogical orientations of the seven workshops. I personally recorded almost 400 pages of field note observations, averaging more than fifty pages for each workshop. These data allowed me to continually reflect on what I was learning and question how cases differed from each other (Eisenhardt, 1989).

Although almost all of the data collection, accompanying instruments, and protocols were taken directly from my proposal, some “flexible and opportunistic data collection methods” were incorporated into this study (Eisenhardt, 1989). Paper evaluations were administered during Workshop A because the .asp versions of the Evaluation Questionnaire and the VNOS Questionnaires had not been completed. Once the online versions were ready I entered the data collected using the paper surveys, ultimately piloting the precision of this online tool.
At first I was disappointed that the web-based instrument was not available to organize and save data for this first workshop, but soon realized that the paper survey allowed me to collect additional information that the field-limited electronic survey would have been unable to capture. For example, several of the teachers within this first workshop indicated that the VNOS questionnaire limited their ability to express how they had experienced a change in their views on the nature of science because it only presented eight potential areas of change. The teachers in the first workshop therefore requested permission to write additional comments about changes that occurred in their views on the nature of science during the workshop on the back of the paper questionnaire. This additional field was easily added to the updated version of the online questionnaire and administered to the participants in subsequent workshops. Of the 87 teachers who completed the questionnaire, 58 chose to respond to this additional field, which ultimately enabled me to enrich the narrative process.

The modification and/or addition to data collection methods during a study is justifiable and legitimate because “investigators are trying to understand each case individually and in as much depth as is feasible” and the goal of the research design was not merely to produce summary statistics about a set of observations (Eisenhardt, 1989, p. 539). When a “new line of thinking emerges during the research” the researcher revises data collection techniques in an attempt to provide better insight into the theory building process. This flexibility does not give the researcher “license to be unsystematic,” but rather should be viewed as an opportunity to take advantage of changing circumstances and new themes that emerge during the data collection process (Eisenhardt, 1989).
Within Case Analysis

While the within case analysis is at the heart of this research design, it is also “the most difficult and the least codified part of the process” (Eisenhardt, 1989). This step allows the researcher to organize and present “write-ups” for each site. “These write-ups are often simply pure descriptions, but are central to the generation of insight” (Eisenhardt, 1989, p. 539).

Some of the data collection techniques, such as the in-class observations and the teachers’ open-ended responses to the questionnaires, were designed to gather sufficient data so that an accurate portrait of each workshop (case) could be presented. The perspectives of the participating teachers have been enfolded into my written description of each workshop in an effort to validate observations and to limit researcher bias, or at least give the reader the opportunity to look for this bias him/herself. The intertwining of the teacher and instructor statements, field notes, and the descriptions made by the 10 trained observers creates a thick, rich description of each workshop (Creswell, 1998). To allow the reader to better understand both the research design and the theoretical framework of this study, the cases have been subdivided so that the data can be viewed through the lenses of both the X-Continuum and Y-Continuum. This process is intended to provide the reader with a better understanding of the unique patterns of each case before the researcher generalizes patterns across cases13 (Eisenhardt, 1989), strengthening the internal validity of this study (Eisenhardt, 1989, p. 540; Miles & Huberman, 1994).

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13 Which occurs in Chapter Five
Y Continuum

The within case data for Dimension Y was collected from four sources: 1) observations including the observational protocol, field notes, and videotape; 2) interviews with the lead instructors; 3) analysis of the evaluation questionnaire; and 4) analysis of course documents.

Two or three trained observers collected both quantitative and qualitative data using the Time-Based Pedagogical Orientation Instrument (Appendix B). Trained observers quantified the pedagogical approach every fifteen minutes and recorded a brief descriptive overview of what occurred in the workshops during these short intervals. These observers also recorded in-depth field notes every hour. Two days of each workshop were videotaped to further validate the data collected by the trained observers. In my field notes I also collected additional observational data related to the pedagogical orientations implemented in each workshop.

The lead instructors of the workshops were interviewed approximately one month after the last workshop. These interviews were intended to assist in the placement of the instructors’ perspectives along the experience-based/syntactic/conceptually-based/substantive continuum. Of the six interview questions (Appendix D), the fourth question was specifically designed to gauge the instructors’ pedagogical orientation, but several of the instructors also commented about their pedagogy while answering other questions.

As expected, the open-ended portion of the questionnaire also proved to be a rich source of data in regards to the pedagogical orientation of the workshop. The teachers
often commented on these orientations used in each workshop when asked what they
“liked best,” “liked least,” or when providing a rationale for the “capsule rating.”
Comments that related to the pedagogical orientation of the workshop were identified and
these responses provided additional perspective and enriched the descriptive analysis of
the Y continuum.

Finally, course documents, including the web page used to advertise the seven
workshops, syllabi, and handouts, were identified and analyzed with the same criteria
used to create the Time-Based Pedagogical Orientation Instrument and the text from
these documents was also used to enrich the descriptive analysis of the Y continuum.

Through all four data collection techniques, I have used teacher and instructor
comments and these other sources of data to create a pedagogical orientation “story line”
(Strauss & Corbin, 1998), allowing me to reflect on both what I have learned about each
case and question how each case differs from the others.

**Workshop A and the Y-Continuum**

In this workshop there were two full time observers (2 & 3) in addition to myself
(1). Observers 2 and 3 had bachelor degrees in the same content area as the workshop
and had each spent approximately one year as a full time graduate student in science
education. Observer 2 had taught high school science for four years and had also
supervised student teachers. Observer 3 had three years work experience in a university
laboratory as a technician.

The course description used to advertise this workshop indicated that experience-
based/syntactic pedagogical approaches would be utilized, stating “the participants in the
workshop will create a definition of a (concept central to this discipline), collect data on (occurrences central to this discipline), and debate (concepts and occurrences central to this discipline).” The workshop syllabus restated this notion by outlining the course schedule in 30-minute intervals, and the descriptions of these intervals seemed to indicate that approximately 8 of the 40 instructional hours were going to be experience-based/syntactic. Teacher comments indicated that these scheduled hands-on activities were intended to provide “clarification or a better understanding of the concepts taught or presented” (2A)\textsuperscript{14}, were “well-connected” to the substantive orientation used in this workshop (1A – also 10D), and “related to topics presented and provided ideas to implement in the classroom” (4A).

After analysis of the classroom observations and teacher comments, most of these scheduled times were classified as conceptual-based/substantive or neutral. 102 15-minute observations in this workshop were recorded by each of the three observers, with an inter-rater reliability of 89%. The workshop used a conceptually-based/substantive pedagogical orientation 84% of the time, an experience-based/syntactic pedagogical approach 3% of the time, and a neutral approach 13% of the time.

Nine (out of ten) teachers made comments that reinforce these observational data, further substantiating that the pedagogical orientation of this workshop was heavily skewed towards the conceptual-based/substantive side of the Y-continuum. Some representative comments are listed below.

**Teacher 3A**

*An incredible amount of new information about (this discipline) was presented and concepts from many other disciplines were introduced and clarified.*

\textsuperscript{14} These codes identify the individual teachers within a workshop. Please note that if the another code is included (also 10D), this indicates that this teacher also attended another workshop(s).
Teacher 5A
The passive learning style of lecture-lecture-lecture, especially when the material is complex and unfamiliar, was overwhelming . . . I realize the scope of the content is huge. The information is detailed.

Teacher 6A
... At times, the continuous lecture format (especially in morning) limited interaction and reflection.

Teacher 7A
PowerPoint is a great tool – but one after another and I tend to “zone out.”

Teacher 8A
There was valuable information presented. The overall workshop provided insightful information, yet it seemed more or less, like a report of what was happening in the scientific arena of (this discipline) through lectures mainly.

Teacher 9A (also 8D)
Great course! I think the material and instructors were great, but I often felt that because of the amount of material to cover in the time frame allotted that the back and forth interactions during the presentations/lecture were limited.

Although the syllabus suggested that a portion of the workshop would use an experience-based/syntactic pedagogical orientation, the lead instructor’s comments during the post workshop interview pointed towards a predominantly conceptually-based/substantive pedagogical orientation. When asked to explain the goals that he has established for the teachers who attend his workshops, and how he facilitated the teachers in achieving these goals, he responded,

My feeling is that we get their attention while they are here, they are a captive audience and we get practically as much into the week as the people are willing to stomach ...My philosophy is that you can bring a horse to a trough, but you cannot make it drink. We just try to lead them to the trough in this workshop.

It should also be noted that the lead instructor indicated that if more funds were available he would attempt to make minor modification to the curriculum of the workshop, but he
did not indicate that the pedagogical orientation would change because of these additional monies:

(With $20,000) I think I would hire someone to work on curriculum for it, particularly the computer demonstrations that we talked about. There is literally nothing else, I don’t have enough time myself that I could devote, so that what I would need in order to develop materials like that would be a trained person that could come in and do that... I’m really primarily a researcher and I can barely find enough time to do the research projects that we are involved in so I personally do not want to buy out to do more teaching. So actually it would not be a good investment with me to give me $20,000, because I probably wouldn’t spend it that well.

**Workshop B and the Y- Continuum**

In this workshop there was one full time observer (6) in addition to myself (1). Observer 6 has a bachelor’s degree in science education that focused on the discipline presented in the workshop, spent one year as an elementary teacher, and was finishing her second year of graduate studies in science education. Observer 6 made 93 15-minute observations in this workshop, while I recorded 44 15-minute observations--approximately 50% of my time was spent in another workshop offered at the same time. A student was hired and trained to record the portions of the workshops that I was not able to attend, but during this workshop she was inconsistent in attendance and with her duties. While some video footage was gathered, the clock was not reset after the battery was drained and I was therefore unable to make systematic 15-minute observations that could be compared to the measurements of Observer 6. Of the 44 15-minute observations that both Observer 6 and I were able to record, there was an inter-rater reliability of 75%.

The first sentence of the course description used to advertise this workshop read, “teachers will engage in hands-on activities … as they develop resources and ideas to
enhance their science programs.” The workshop syllabus also seemed to indicate that a significant portion of this workshop would use an experience-based/syntactic pedagogical orientation by scheduling 90 minutes on each of the first four days; approximately 6 of the 36 instructional hours.

In the post workshop interview the lead instructor affirmed that he intended for the workshop to communicate an experience-based/syntactic orientation:

(\textit{The teachers}) break the myth that science is perfect and is done this way and they get a chance to see how dirty the process is, and, \ldots they see how many persons are working on one topic, it’s kind of a beehive effect as opposed to Einstein popping the answer out.

However, classroom observations classified most of these scheduled times as conceptual-based/substantive or neutral. Observer 6’s data indicated that the instructors of this workshop used a substantive pedagogical orientation 70\% of the time and a neutral approach 30\% of the time. Also, 8 of the 16 teachers commented frequently in the questionnaire about the conceptually-based/substantive pedagogical orientation used in this workshop, making comments like,

\textbf{Teacher 3B}
\textit{The lectures \ldots were too in-depth for complete understanding of the concepts \ldots make it more relevant (by) remember(ing) (that) most teachers, while exposed to depth in college, are extremely out of practice with the details.}

\textbf{Teacher 7B (also 12G)}
\textit{Lectures really were "above" the heads of most participants in the room\ldots I expected some of this, but in conversations with other teachers, it was apparent that they felt the same way about most of the lectures.}

\textbf{Teacher 8B}
\textit{The science lectures \ldots only explain things in scientific terms and not in terms of educational application.}

A former teacher who had attended previous workshops was hired to test, develop, and present activities to the teachers that related to the theme of the workshop. However, it should be noted that these activities were primarily used to verify concepts
that had already been presented in the lecture portion of the class, and were not reflective
of scientific processes. For this reason, both Observer 6 and I categorized these activities
as conceptually-based/substantive.

My field notes and teacher comments suggest that the very systematic schedule
was the primary reason the observers quantified a fairly large percentage of the workshop
as “neutral.” Each day’s schedule was presented to the teachers in table format, with
equal numbers of rows and columns: from 9:00 – 10:45 there was a tour; from 10:45 –
10:00 a break; from 11:00 – 11:45 a research lecture; from 11:45 – 1:00, lunch; from 1:00
– 3:15 an “activity;” from 3:15 – 3:30 another break; from 3:30 – 5:00 there was a second
activity…etc. This structure allowed rooms to be easily reserved and instructors and
teachers know what to expect. The disadvantage of this structure was that different
lectures, activities, and tours tended to vary in length, disrupting the schedule whenever
an event went overtime or, more commonly, under-time. These unanticipated long
breaks caused this workshop to have a lower “time-on-task” ratio than the other
workshops.

**Workshop C and the Y - Continuum**

In this workshop there were two full time observers (4 & 5) in addition to myself
(1). Observer 4 had a bachelor degree in a physical science, and had a few years of work
experience as a technician in that discipline. Observer 5 had a bachelor’s degree in
elementary education. Both Observers had just completed their first year of full time
graduate work in science education. In this workshop the student recorder came on both
days (when I was attending the other workshop), and remembered to set the timer on the
video camera. Therefore all three observers were able to record 111 15-minute
observations, with an inter-rater reliability of 94%. The workshop used a substantive pedagogical orientation 100% of the time.

Interestingly, even with an inter-rater reliability of 94% indicating that the entire workshop used a conceptually-based/substantive pedagogical orientation, the lead instructor in the post workshop indicated that he utilized a mixture of experience-based/syntactic and conceptually based/substantive approaches in the design and implementation of his workshop. When asked in the post workshop interview how he would respond if a teacher called and asked him to explain his expectations of the participants who attended this workshop, he responded,

_Basically because the teachers that come to us have an interest in (this discipline), really what we want to do is make sure that they are getting out of the workshop what they wanted when they came in ... whether it is a selection of inquiry based activities, to teach content that they already understand, or to update their content to the most modern cutting edge thing so that they can incorporate that into a course that they already teach..._

When asked what goals he established for teachers who attended the workshop, the instructor again indicated that both experience-based/syntactic and conceptually-based/substantive pedagogical orientations were used in this workshop:

_So the goals we have is that they can create a course if that is what they are interested in, or they can use what we teach them to teach a topic that they already are teaching but from (this discipline’s) perspective instead of maybe a physics perspective or earth science perspective. And facilitating that is just the way we have structured things, we try to mix in content lectures, keeping close to the layout of the text book, some subset of activities, demonstrations, laboratories, and one thing that we’ve been asked to do is research talks...just seeing that research talk is useful to them because it gives them anecdotes to use in the classroom, and just an appreciation of the process of science._

These statements are consistent with the language used in the course description presented in the advertisement—“The participants in the workshop will perform hands-on classroom laboratory experiments with inexpensive equipment, examine multimedia
curricular material, do (related scientific observation), and explore the uses of (scientific instrumentation).” The workshop syllabus restated this notion by outlining the course schedule, indicating that more than 9 of the 40 instructional hours were going to be experience-based/syntactic. These scheduled activities were intended to engage teachers in computer-modeling programs, classroom demonstration, scientific observations, and laboratory protocols.

It should also be noted that when the instructor was asked if he would change the workshop if additional funds were available, he indicated that he was pleased with the current format but was interested in introducing a new workshop that was more “inquiry” based:

But I think that a new one, a new workshop... where we immerse them into inquiry...using real data, and analyzing real data with the software we use and getting a answer, and relating that back to the content that they have gotten in bits and pieces, so I really think that there is room for an entirely new experience.

The teachers’ comments from the open-ended portion of the evaluation indicate that a vast majority of the workshop’s pedagogical orientation was conceptual-based/substantive:

Teacher 1C
Content, content, content (A teacher commenting about what he liked best about the workshop.)

Teacher 2C
I liked the fact that I was exposed to such an array of facts... I feel as though I would have benefited more from a hands on approach.

Teacher 3C
(In response to what the teacher liked least) Sitting so long. Some of the lectures were too long and too in depth for a high school or middle school level... Maybe provide more hands on activities instead of so much lecture. After a while it was hard to stay focused.

Teacher 4C
I found there were too many elements of passive learning and not enough inquiry activities within the workshop. I wanted to be challenged and stimulated. Some of the lecturers were exciting and stimulating, others were boring and obtuse.

Teacher 5C
The entire week was lectures on scientific topics by scientists.

Teacher 6C
The constant lecture style presentation was hard to internalize.

Teacher 7C
There were times when we were presented with content that needed some “absorption” time, but due to the time constraints, we move immediately to the next concept or talk.

Teacher 9C
Many times I had reached a saturation point and could not stay with lectures after sitting for too long. The afternoons became especially long and tiring.

Teacher 11C (also 9F)
The lectures got to be a little long and confusing. .......I would have liked to have seen a little more science inquiry type activities put into the workshop and then discussed on how to implement them into different classrooms. We received a lot of information

**Workshop D and the Y-Continuum**

In this workshop there was one full time observer (3) in addition to myself (1). This observer had bachelor’s degrees in the same content area as the workshop and has worked full time as a university laboratory technician in this discipline for the past three years, during which time he has also enrolled as a part-time graduate student in science education. It should be noted that Observer 3 also observed Workshop A. Both Observer 3 and I recorded 107 15-minute observations in this workshop, with an inter-rater reliability of 92%. The workshop used a conceptual-based/substantive pedagogical orientation 83% of the time, and a neutral approach 17% of the time.

One reason that a portion of this workshop was neutral was because it started with a four-hour logistical overview on Monday morning. Most of the other workshops
presented an overview of logistics on Sunday night, enabling the instructors to start
presenting on Monday morning.

The initial sentence of the course description used to advertise this workshop
indicated that the purpose of the laboratory was to reinforce the substantive components
of this discipline, stating, “the participants in the workshop will explore the basic
principles of (concepts and occurrences central to the research of this discipline) while
conducting hands-on experiments in a research laboratory.” However, the next few
sentences identify an experience-based/syntactic orientation—“The educators will learn
about contemporary research methods and models and will get firsthand experience with
techniques such as (list of techniques). Laboratory work will be integrated with research
discussions led by invited scientists addressing hot topics in (this discipline).” The
workshop syllabus also seemed to point towards an experience-based/syntactic approach,
scheduling approximately 11 laboratory-based hours in the 40-hour week.

There were two lead instructors, each responsible for a portion of the workshop.
The first instructor was responsible for the explicit presentation of subject matter and
running the lab activities. The other instructor was responsible for introducing
educational resources related to the subject matter. There was not a clear, iterative
connection/overlap between the presentation of resources and the curriculum of the
workshop. In the post workshop interview, the first instructor’s comments suggested that
he hoped that the teachers would come to a better understanding of both the substantive
and syntactic aspects of science by participating in this workshop:

(The teachers) have seen from the hands on activities that they are doing, that from the
point of view of people who are actually doing this, these kinds of experimental
approaches are very well laid down already, that teachers like them, new teachers, can
do these. In other words, there is nothing so mysterious about doing science once these
methods are understood and established. So, of course the other part of that also is that
the fact that the hands on, what you are doing, is discussed and explained in a very
understandable way. Although what they are doing is a lot of hands on, it’s really a lot
of minds on. And by combining those two, really actually seeing science in action, and
understanding a lot of the basic principles that go into that, I think that spirals into their
understanding of science in general and how things are done in science.

The second instructor had a similar epistemological perspective, stating,

*I almost feel like we are deprogramming everybody by the time they are in post-
secondary education arena, whether it is here as a K-12 student, or here as a teacher, or
here as a whatever, we are almost deprogramming them to understand that science is a
process that starts with ignorance and educated guessing rather than knowing
everything. I find that really strange. Again, I think it goes to my whole philosophy on
learning science; learning science has to be hands on. And the workshop has to be a
result of that.*

In the open ended portion of the questionnaire 9 of the 11 teachers referenced the
“hands on” or “laboratory” activities as a central portion of this workshop. Yet most of
these teachers stated that these labs facilitated in their understanding of the “concepts” or
“information” presented in this course and not one comment was made about scientific
processes. Most of the comments made in the questionnaire pointed towards the
conceptually-based/substantive nature of this workshop. Here are some of the statements
made in the open-ended questionnaire:

Teacher 3D
*Needed some introduction into (the basic concepts of this discipline) so that all
participants can start off at the same level when getting into the serious lectures. Need to
get up and move around - a two-hour lecture is too long without a break.*

Teacher 4D
*The lectures and laboratory experiences were well organized and skillfully presented.
The only weakness I felt was that some teachers felt they did not have the background to
understand many of the technical concepts presented. As a group of teachers this may
have been a strength in that those of us who had background in the technical side of the
study helped the teachers who did not have the necessary background.*

Teacher 5D
*I felt that the lecture and lab components of the workshop were skillfully coordinated. I
loved the intensity of the information.*
I could relate the frustration my students sometimes feel when they do not thoroughly understand a particular concept. I guess if this is what I liked least, it wasn’t all that bad. Besides, I learned something valuable.

The ineptness I felt at the start of the workshop might have been less intense if I had been more prepared. … I strongly recommend including a vocabulary list and a basic concept guide sheet with the preworkshop materials.

I found the technical information overwhelming at times, but I expected this workshop to be intense and expect a lot from me - but I would rather (have) a challenging workshop than one that is really ‘watered down' and over-simplified. I know a couple of students may have complained about the homework that was assigned, but it really did force us to apply what we have learned and bond with the other teachers.

Workshop E and the Y Continuum

In this workshop there was one full time observer (9) in addition to myself (1). This observer was a senior undergraduate student pursuing a degree in science education. Observer 9 made 110 15-minute observations in this workshop, while I recorded 53 15-minute observations because approximately 50% of my time was spent in another workshop that was offered at the same time. Unfortunately, I had not resolved the difficulties experienced in Workshop C, so although the portions of the workshop that I did not attend were recorded, the clock on the camera was not reset and I was therefore unable to make systematic 15-minute observations that could be compared to the measurements of Observer 6. Of the 53 15-minute observations that both Observer 9 and I were able to reconcile, there was an inter-rater reliability of 85%.

The portion of the course description used to advertise this workshop indicated that an experience-based/syntactic pedagogical approach would be utilized by stating, “The participants in the workshop will interpret patterns (in this discipline using different
instruments) and produce (scientific reports) that they can share with their students.”

Although this workshop syllabus did not clearly delineate the schedule into discrete intervals, the scheduled time seemed to indicate that a significant portion of the 40 instructional hours was going to use an experience-based/syntactic pedagogical orientation. These scheduled activities suggested that teachers would be engaged in computer modeling and the production of scientific reports.

However, after close classroom observation many of the scheduled experience-based/syntactic times turned out to be conceptual-based/substantive or neutral. According to the observations recorded by Observer 9, the workshop used a conceptual-based/substantive pedagogical orientation 99% of the time and a neutral approach 1% of the time.

Several teachers made comments that reinforced our observations, stating, “Much of the workshop was a lecture. More inquiry based learning would make it more interesting and hands on” (8E). 3E commented that he would have liked “to see more hands-on applications of the concepts.” Another teacher (9E) expressed a different perspective about the pedagogical orientation of the workshop—“We as a class were engaged in many activities throughout the session to effectively challenge and encourage us to seek out answers. This then led to a further inquiry and more knowledge.” This teacher’s perspective, however, was the exception:

Teacher 1E
This workshop provided me with a great deal of knowledge on (this discipline). Some of the material I learned for the first time, some I was relearning due to having been taught it incorrectly in prior years by other educational institutions.

Teacher 2E (Also 2G)
A vast amount of information was presented across many interests within (this discipline).
Teacher 4E
I thought that the information presented in the workshop was absolutely fantastic and that all of the speakers were very well prepared and gave excellent lectures. The speakers all had very accomplished backgrounds and it was nice to hear from so many experts. However...90% of the workshop was lectures. While they were all very engaging there was not much time for teachers to collaborate or investigate with ways to incorporate the information learned into classroom.

Teacher 5E
Some days it felt like there was too much (lecture). I would shorten some of the speakers’ presentations.

As indicated by our in-class observations, about 90% of the workshop was conceptual-based/substantive. During the post workshop interviews the two lead instructors were asked what their expectations were for the teachers who attended the workshops. Their responses were both consistent with what actually occurred in the workshop and were more reflective of a conceptual-based/substantive pedagogical orientation.

Instructor 1
I will say that (this workshop) is intended as a refresher, as an invigorator, as an overview. This is intended to reacquaint the teacher with basic concepts to shore up any uncertainties in their knowledge base, to expand their knowledge with regard to research that has been done in the field, to offer collegiality among their fellow teachers and people who are totally immersed in this field, and to provide resources for them that they may or may not have had prior (to this experience).

Instructor 2
A deeper understanding of the science... at least what I’m thinking of is, that gee, they come here, they are spending good money to get here, they want to go back with some things and those things are a deeper knowledge and some actual lessons that they can without killing themselves bring into the classroom and hopefully then make their students more (science) savvy, better (science) consumers.

Instructor 1 followed up by stating,
I would say that we have met our goal for (this workshop)... if the teachers leave here with a sense of confidence, renewed confidence, in their ability to instruct in (this) part of (this) science curriculum.

Workshop F and the Y-Continuum

In this workshop there were two full time observers (6 & 7) in addition to myself (1). Observer 6 had a bachelor degree in science education that focused on the discipline presented in this workshop, spent one year as an elementary teacher, and was finishing her second year of graduate studies in science education. It should be noted that Observer 6 also attended Workshop B. Observer 7 had a bachelor’s degree in the discipline that the workshop focused on and was completing both her certification and masters program in science education. In this workshop the student recorder attended on both days that I was at the other workshop and remembered to set the timer on the video camera. Therefore all three observers were able to record 101 15-minute observations in this workshop with an inter-rater reliability of 100%.

The portion of the course description used to advertise this workshop indicated that an experience-based/syntactic pedagogical approach would be utilized by stating, “The participants in the workshop will perform hands-on, PC-based data analysis of real (scientific) data, examine multimedia curricular materials, (make scientific observations), and (explore the uses of scientific instrumentation).” The syllabus clearly delineated the workshop schedule into discrete 30-minute intervals; the scheduled time seemed to indicate that several of the 40 instructional hours were going to use an experience-based/syntactic pedagogical orientation. This does not count the six hours of extracurricular activities planned into the workshop.
After close classroom observation all of the scheduled experience-based/syntactic times were classified as conceptual-based/substantive—this workshop used a substantive pedagogical orientation 100% of the time.

When asked about the goals that he established for the teachers, the lead instructor of this workshop was very direct in saying that his desire was to present content:

*We want to certainly give them the content necessary to teach their students at the level recommended by the Pennsylvania Science Standards and the National Science Standards. And I think that we do that fairly effectively. Those science standards, which you've probably read, are fairly terse. They don't actually flesh things out. I think that is one of the goals, to get it so that they can teach their kids at that level. And how can we facilitate teachers in achieving those goals, well, you witnessed how you do it. We teach them the content, we let them ask questions back and forth, we give them the materials to be able to address these things.*

When asked to elaborate on the teacher’s role in the workshop, the lead instructor responded,

*Well, when they come to my workshop, I’m sorry, I don’t want to be unpleasant, but they don’t actually do science. They aren’t at the level where they could do that effectively. Again, going back to your previous question, what they can do, is see people who are doing science and ask them about what they do and ask them about what motivates them and why this is important. But they don’t come into my workshop and start analyzing some data... At that level it just doesn’t seem feasible... I just don’t think they are at the level where they can do that effectively.*

Although the instructor’s comments seem to imply that the workshop’s approach would facilitate teachers in generating and establishing new knowledge claims because it introduces them to scientists “*who are doing science,*” the comments made by 10 (out of 10) teachers in the written portion of the evaluation appear to substantiate our observations about the substantive/conceptual-based pedagogical orientation of this workshop. Here are a few examples:

Teacher 2F (also 13C)
Much of the workshop was content driven in traditional lecture format. I think most of the participants wanted a great deal of content so I wouldn’t really like to see this changed.

Teacher 3F
I would STRONGLY recommend that (the instructors) brush up on recent pedagogical theory as well as on new findings in the field of brain research. They are so knowledgeable - if this course could actually engage the teachers in a meaningful and applicable way, it would be a fantastic course. In this workshop, teachers were SOLEY passive recipients of information. There were no "higher level thinking" learning methods involved AT ALL - no hands-on, constructivist learning, much less anything involving the synthesis of the vast amounts of information presented. There was no structure inherent or planned in the workshop that allowed the teachers to interact and exchange or develop ideas in which to incorporate the information presented into a curriculum.

Teacher 4F (Also 5B)
(The lead instructor) was precise with the information and had an outstanding domain of the subject. His organization of the material was also very clear and coherent... I strongly believe that the content was exceptional, however there was little opportunity to engage in discussion and to be free to ask questions.

Teacher 5F
I am so impressed with the quality of the content area instruction and relieved that I did not have to spend hours on ‘fun’ classroom activities.

Teacher 8F (also 10C, 11E)
This course was excellent in terms of the science content that was introduced, as someone with limited knowledge in the content area, I learned a great deal within this course.

Teacher 9F (also 11C)
I really enjoyed the content of the workshop and the new research talks that were brought in. It is so exciting to be informed of the latest cutting edge research...

It should be noted that the lead instructor indicated that if he had access to more funds, he would not necessarily use those monies to change the pedagogical orientation of the workshop,

Well one thing I would do is hire a good undergraduate. Someone, for example, who had taken one or two introductory (courses in this discipline) and done well in them, to help just updating the (curriculum) of the course...
Like the instructor of Workshop A, this instructor indicated that time was more of a limiting factor than money in the design and implementation of his workshop, but even with more time, he would not strive to change the basic structure or pedagogical orientation of the workshop:

*I think that some of the curricular materials could use updating both in terms of recent discoveries that have been made and in terms of making them more accessible, you know in a nice glossy format or put them on the worldwide web or something so that the teachers could work through it. So I would hire someone who would just want to do some of that work. And it’s not extraordinarily difficult work. But it takes someone with some basic knowledge and dedication... I don’t think that the workshop is lacking in some particular way where if I just had some more money it could all be better.*

**Workshop G and the Y-Continuum**

In this workshop there was one full time observer (8) in addition to myself (1). This observer was a recent graduate with a degree in science education. Observer 8 and I each made 92 15-minute observations in this workshop and had an inter-rater reliability of 91%.

The portion of the course description used to advertise this workshop indicated that an experience-based/syntactic pedagogical approach would be utilized by stating, “Educators will be immersed in a real-life scenario …, and they will face the same decision-making process that is routine in (this discipline). This new workshop will focus more specifically on (the decision-making processes that are routine in this discipline) than on the more broad topics covered in (workshop E, the other workshop in this discipline). Each educator will (present his scientific findings and receive a CD, Web resources, and print materials that they may share with their students.” Although the workshop syllabus did not clearly delineate the schedule into discrete time intervals, the scheduled time seemed to indicate that more than half of the 40 instructional hours were
going to utilize an experience-based/syntactic pedagogical orientation to actualize this “real-life scenario.”

When asked about the goals that he had established for the teachers who attended this workshop, the lead instructor responded that he desired to incorporate both the substantive and syntactic aspects of science into this workshop:

*(This) workshop is intended to address a specific problem or challenge within (this science): It is not the only issue that is addressed within the science but it is the one that we would address in the workshop. And to do it in a way that we trust that both the method that is presented as well as the processes that are shown are instructive in regards to the scientific methodology. The way (this problem solving) is done as well as the way we present (this) problem are both constructive to that goal. I would say for (this) workshop that we have met our goal if the teachers have left here with more of a sense of the “Wow! I didn’t realize that all this went into (this type of problem solving), I didn’t understand,” that they have a deeper appreciation for this process as well as some ideas on how they can implement it into their own classroom.*

The lead instructor indicated that if provided with additional funds, he would pursue the experience-based/syntactic pedagogical orientation more vigorously:

*I would very much like to create an … simulation, I would like to take some of our numerical models … and put these on various workstations that we have here and get the data set and have the teachers actually run our computer (models), I would like to have them do it, and teach them how to change some relatively simple parameters to see how that changes the (environment), I really like to get them into that type of a simulation. It requires some upfront money because of computer space, time, upfront preparation, but that is what I would like to do………. I think there are two things, if I had a goal with funds. There would be two or three purposes. One would be to raise the level of simulation and participation that gets the teachers closer to the reality of the science. Um, that to me is a wise investment as to the quality of the workshop.*

However, after close classroom observation, most of the scheduled experience-based/syntactic times were classified as using a conceptual-based/substantive pedagogical approach. According to our observations, the workshop used a substantive pedagogical orientation 85% of the time, a syntactic pedagogical orientation 3% of the time, and a neutral approach 12% of the time. In the evaluations, 7 of the 15 teachers indicated that
while the simulation provided a theme for the content and lectures of this workshop to be organized around, it did not engage the teachers in the process of problem solving within this discipline, but rather focused on the concepts and content related to methods related to this discipline (5G). Teacher 14G stated

*Overall, the workshop was very similar in design to (another workshop attended during this summer). I thought that (this) workshop would have focused more on making (physical models), and explaining systems and processes rather than just focusing on the overall methods of (this type of problem solving).*

Teacher 14G continues to explain why over 12% of the instructional time was categorized as “neutral.”

*There seemed to be a lot of downtime during the week (breaks, wasted time, etc.) I really dislike wasting valuable time. If we come here for a required length of time as per course requirements, that is fine, but I struggled to keep focused this week.*

**A reminder to the reader—**

Chapter 4 allowed me to organize and present “write-ups” for each site to the reader. *These write-ups are often simply pure descriptions, but are central to the generation of insight* (Eisenhardt, 1989, p. 539).

While the intertwining of the teacher and instructor statements, field notes, and the descriptions made by the 10 trained observers creates a thick, rich description of each workshop (Creswell, 1998), an analysis of the Y-Continuum is presented in Chapter 5 starting on page 101.
Continuum X-- The Professional-Technician Continuum

The open-ended portion of the questionnaire proved to be a rich source of data with respect to defining workshops along the Professional-Technician X Continuum. The teachers often commented on how they were treated as professionals or technicians when asked what they “liked best,” “liked least,” or when providing a rationale for the “capsule rating,” and these responses provided another “flexible and opportunistic data collection method” (Eisenhardt, 1989).

Both the field notes and the coded teachers’ comments have enabled me to generate a rich description of how teachers were treated as technicians or professionals. To allow these descriptive data to speak for themselves, I have used portions of the original teachers’ comments in an attempt to create an accurate description of this aspect of the professional development environment.

The Coding Dictionary (Table 15) provides a definition for each of the five codes along with a representative example of a coded teacher statement. Because each of the codes was intended to be value neutral, I generated an organizational method by which I could keep track of the positive or negative sentiments communicated through the teacher statements. For example, if a teacher’s comments described the professional development context as inaccessible, Code P-1 was used, and my organization method assigned a minus sign (-) to that particular code. Similarly, a plus sign (+) or no sign was also used to help frame teacher statements. The reader will notice that both positive and negative comments are included in the same section of the workshop description and often these differing perspectives are compared and contrasted.
The other results pertaining to the X continuum are presented in the cross case analysis because this information was analyzed by looking at the data for all the workshops collectively, and the findings in this section were viewed through an analytical lens that had already seen the data from the other contexts.

<table>
<thead>
<tr>
<th>Code Name and Number</th>
<th>Code Definition</th>
<th>Example of Teacher Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>P-1 – Accessibility</strong></td>
<td>In these professional development environments, professional developers who are content experts make themselves accessible to teachers and engage them as peers by recognizing their “instructional expertise” (Joyce &amp; Showers, 2002; Tillema &amp; Imants, 1995, p. 147).</td>
<td>The ability to interact and converse with instructors in class and on a one to one basis during break time and during transport to other sites. Having instructors that are experts in their fields and being able to converse and interact with them on a personal basis.</td>
</tr>
<tr>
<td><strong>P-2 – Collaborative and Flexible</strong></td>
<td>In these professional development environments, professional developers empower teachers to assume these new roles by promoting collaborative and flexible learning environments (Hargreaves, 1994; Joyce &amp; Showers, 2002)</td>
<td>Without a doubt, every one of the instructors at this workshop provided not only essential material, but skillful facilitation, purposeful discussions, and great flexibility in response to our needs. In short, it was a great experience! I enjoyed the free interchange atmosphere at all sessions. I enjoyed immensely the collaboration sparked by the “homework assignments.”</td>
</tr>
<tr>
<td><strong>P-3 – Reflective Practitioner</strong></td>
<td>In these professional development environments, professional developers that recognize these skills and knowledge encourage teachers to reflect on their professional practice (Joyce &amp; Showers, 2002; Schön, 1991).</td>
<td>I especially liked the dialogue at lunch regarding snowball earth where different scientists had different interpretations… I always enjoy dialogue with other teachers - how do you teach? What is your system like?</td>
</tr>
<tr>
<td><strong>T-1 – Delineated Roles and Structured Time Use</strong></td>
<td>Professional development environments guided by this orientation have the tendency to clearly delineate roles: the professional developer provides the information and the teacher adopts it (Tillema &amp; Imants, 1995, p. 147). Time use in these environments, is an “objective variable, an instrumental, organizational condition that can be managerially manipulated in order to foster the implementation of educational changes whose purpose and desirability have been determined elsewhere” (Hargreaves, 1994, p. 96; Schön, 1991).</td>
<td>The instructor had a very structured format, well-organized, that he felt shouldn't be deviated from in order for us to learn the material sequentially. So if we asked a question that was &quot;ahead of the schedule&quot; he usually deferred to answering it later. Although I understood his reasoning this led the participant to feel less encouraged to ask questions at all.</td>
</tr>
</tbody>
</table>
Workshop A and the X-Continuum

A - Professionalism

While the teachers in Workshop A had differing perceptions on the accessibility of the instructors (P-1), three indicated that they “were encouraged to ask questions, and appropriate responses were always given” (1A).

Four of the ten teachers indicated that this workshop’s instructors fostered a flexible and collaborative environment (P-2), commenting that “there was a warm sense of congeniality” (10D) even when “different scientists had different interpretations …. and different conclusions ….. from similar data” (7A). Teacher 3A appreciated “the freedom to ask questions about new material and stuff tangentially related, that has confused (her) for years.” Conversely, teacher 10A (also 2D) suggested that the collaborative environment could be improved by “soliciting teacher's classroom experience and student needs at various levels may provide food for thought.”

Five of the teachers commented that interactive/reflective time (P-3) was limited in this workshop. Teacher 6A explained that the “format limited interaction and reflection.” Teacher 5A concurred by stating “insufficient time and discussion was provided for application of information to classroom use. There was almost no time for absorbing and reflecting on the information provided.”
A - Technician

The comments pertaining to “teacher as technician” focused on how the workshop instructors understood the needs of the teacher participants and how they determined which predetermined skills, content, and resources the teachers needed (T-2). Teachers indicated that “there were well-connected "hands on" activities that could be easily adapted for use in the classrooms of most participants” (1A, also 10D) and “the discussions and hands-on activities related to topics presented and provided ideas to implement in the classroom” (4A).

Teachers 6A and 5A both commented on how two of the instructors “presented at an excellent level for comprehension” while one of the other instructors “was difficult to follow” and did not present at a level “geared towards all backgrounds.” After establishing herself as a teacher with in-depth scientific background, Teacher 7A indicated that although she enjoyed the workshop, “some (other) participants were elementary teachers… and for them it was harder to follow some topics.” Teacher 8A, a secondary science teacher with a bachelor’s of science, stated that “sometimes... the information was a bit technical, hard to understand if the participant had very little subject content,” and even with her more comprehensive subject matter background, she “would have appreciated some of the lectures better had (she) been a lot more familiar in lecture areas.”

Workshop B and the X-Continuum

B - Professionalism

6 of the 16 teachers responded positively about this workshop’s collaborative and flexible environment (P-2). Teachers 2B, 3B, 5B (also 4F), and 14B (also 6E) each
appreciated the opportunity to “interact” and “share ideas.” Teacher 13B commented that “flexibility” was what she liked best about the workshop because the “instructors were very knowledgeable and adaptive to many different needs.” Teacher 16B concurred by stating that “the workshop was artfully implemented, with flexibility and responsiveness to teacher needs and interests.”

Three of the teachers thought that the workshop did not provide them with adequate time to reflect on their professional practice (P-3). Teacher 9B stated that one of the “weaknesses in this course” was that “there was limited time for teachers to share ideas of how these activities would work in their classrooms.” Teacher 12B expanded on this idea by stating that the “lectures and explanations could have been shortened to allow for more time for teachers’ discussions of topics and relevant activities, more time for participating with activities, and more time for reflection. Less talking, more doing!” Teacher 15B suggests that there was “too little time to reflect upon implementation as a group.” The in class observations suggest that while the instructors of this workshop provided more free time than any other six workshops, the time was not structured to encourage teacher reflection and interaction.

B - Technician

Twelve of the sixteen teachers commented positively on the predetermined skills and content taught and the resources presented (T-2). Teachers 1B, 2B, 4B, 7B (also 12G), 8B, 9B, 10B, 11B, 12B, 13B, 15B, 16B all cited the “tours and activities” as what they “liked best.”
Although the presentation of content and resources was the main focus of this workshop, teachers 2B, 3B, 6B, 7B (also 12G), 8B, 9B, 11B, 12B, 13B, and 14B (also 6G) each stated that the professional developers did not understand the needs of the teacher (T-2), and did not address how the above mentioned materials and content could be transferred to the K-12 classroom.

Teacher 2B stated that “the activities were excellent ideas, but at times they needed to be modified in some manner to make them applicable to the high school classroom” Teacher 3B agreed by stating that these activities “need(ed) more relevant applications to high school science classrooms.” Teacher 7B (also 12G) believed that the activities “would be fairly impossible for (him) to implement in (the K12) classroom” and that there was “very little that (he) could take back into my classroom this fall, which was overall disappointing.”

Teacher 7B (also 12G) stated that the “lectures really were "above" the heads of most participants in the room.” Several other teachers concurred, commenting on how “lectures were extremely scientific, in which many of the teachers could not relate” (Teacher 8B), “the scientific talks … were long and out of touch with the teachers” (Teacher 9B), and “the formal lecture topics were handled in a manner that was too advanced for the educational background of at least some of the participants” (Teacher 14B, also 6G).

Another indication that this workshop followed a more “teacher as technician” orientation was the very systematic time use (T-1). This rigid schedule caused this workshop to have unanticipated long breaks and a lower “time-on-task” ratio. “Because the (schedule) was set ‘in stone’, the adaptations were limited” and because of this,
“some participants did not get the point that this workshop was to show how (this discipline) is multidisciplinary and that … connecting to other sciences is a good thing” (Teacher 4B).

The lead instructor’s tendency to treat the teachers more like technicians through his time use is also revealed in the language used in the interview conducted approximately one month after the workshop. When asked how the day-to-day work of K-12 science teachers differed from university instructors, he described teacher’s time use (T-1) as “an organizational condition that can be managerially manipulated in order to foster the implementation of educational changes whose purpose and desirability have been determined elsewhere” (Hargreaves, 1995, p. 96; Schèon, 1991):

Science teachers have a pretty set and rigorous (schedule), and it is pretty mapped out, 8-5 or 8-3, or whatever they do... The main difference I can tell you from my experience is that (K-12) teachers talk to fill up time, and not to say what they are doing is not important, but there is a lot more classroom management skills that are necessary, and since they have so many hours and no prep time—there prep has to be done during the summer and from their experience in the past, it’s more about, I don’t want to say baby sitting, but they have to fill their time.

**Workshop C and the X - Continuum**

**C - Professionalism**

Teacher 3C commented on how the instructors facilitated a collaborative environment (P-2), by “treating (teachers) as adults” with “real jobs and lives” and “not as the typical undergrad student.” She continued to comment that often professors who offer professional development “find it hard to leave that mode of teaching.”

Conversely, five of the teachers made pointed comments on the negative workshop environment, suggesting collaboration between participants was limited due to
the existing conditions. Teacher 11C (also 9F) commented that the workshop
environment allowed by the instructors did not facilitate collaboration among teachers.
Teacher 7C commented that “cell phones going off and rude participants” were what she
liked least about the workshop. Teacher 9C stated that she “understood the desire to have
participants participate, but rudeness (of fellow participants) should not be tolerated.
Participants who dominate discussions with inappropriate comments should not be
tolerated.” She continued to explain that “one of our participants would be talking and
interjecting comments as a speaker was presenting” and expressed that “this should have
been dealt with on a one-on-one basis.” Teacher 10C (also 8F, 11E) also commented that
teacher 8C (also 7F) was “LOUD, would NOT listen and acted like she already knew
everything.” She concluded by telling the instructors that they “should have done more to
intervene.” Teacher 13C (also 2F) joined in on bashing Teacher 8C (also 7F) by calling
her “the irritating participant who although was knowledgeable and experienced felt the
need to always prove that to every instructor.” Teachers 9C and 10C (also 8F, 11E) sat
together during the workshop, but teachers 7C and 13C (also 2F) were usually located in
a different section of the room. Teacher 8C (also 7F) did impact the overall workshop
culture and animosity between some teachers and instructors created by this issue
appeared to detract from the workshop’s professional environment.

Interestingly, only Teacher 8C (also 7F) perceived the workshop instructors as
being both flexible and accessible (P-2 and P-1), and commented that “if people were
tired or they felt that a particular lesson or talk would not work, (the instructors) either
rescheduled it or shuffled it around. They took into account that people were tired and did
not schedule (an activity) the first night and took suggestions of the group into
consideration throughout the workshop. They were a fabulous group of individuals who took a personal note of us and bent over backwards to make sure our experience was (great).” Teacher 1C commented on the instructors’ willingness to be flexible and Teacher 13C described the instructors as “accessible.”

Teacher 11C (also 9F) remarked that the teachers needed to be given the opportunity “to evaluate and think for themselves”, indicating that the teachers were not provided with ample time to reflect on their professional practice (P-3).

C - Technician

8 of the 14 teachers comments revealed that the professional developers’ treated the teachers as technicians through their time use and delivery of information (T-1). Teacher 1C stated, “some sessions were far too long for teachers who are accustomed to 42 minute time slots for the delivery of material.” Teacher 2C “was not very keen on the amount of time that (they) were required to sit and listen” and suggested that he “would have benefited more by being given the opportunity to share ideas as to how the knowledge and facts gained would be best applicable in the classroom.” Teacher 4C commented on the “lack of active participation in a meaningful activity other than note-taking (and) found there were too many elements of passive learning.” Teacher 6C commented on how “the constant lecture style presentation was hard to internalize.” Teacher 7C also expressed the structure of the workshop did not allow for adequate "absorption time” for difficult concepts. Teacher 8C (also 7F) agreed with the other teachers that the “long days” were what she liked least about the workshop, “but felt they were necessary and needed in the structure of the workshop.”
Teachers 2C, 4C, 6C, 8C (also 7F), and 9C all appreciated the resources and curriculum that the workshop instructors presented because the information was easily transferable into the K-12 classrooms (T-2). However, several of these same teachers indicated that the workshop instructors did not understand of the needs of teachers. Teacher 2C described the workshop as “an overwhelming display of instructor knowledge” where he “was given a wonderful array of facts but not many strategies as to how to use the information in a meaningful and effective manner.” He continued to describe himself as “bystander”, and suggested that a “more practical application of this knowledge would have been far more beneficial that simply being given fact after fact and research idea after idea.” Teacher 4C suggested that the “instructors should have taken the time to determine what (the teachers) knew before each lecture.”

In the post workshop interview the lead instructor expressed that he understood what the teachers “want to get out of the workshop” and described his workshop as being collaborative, interactive, and inquiry-based. He explained that the reason teachers “come to us” is to improve their understanding of the content, and he suggested that the workshop was pitched at an appropriate level that meets the teachers’ curricular and pedagogical needs.

Workshop D and the X-Continuum

D - Professionalism

Teacher 6D made numerous comments that indicated that this workshop promoted a collaborative and flexible learning environment (P-2). In regards to collaboration, Teacher 6D cited “interacting with other science teachers” as what she
liked best about the workshop. She also indicated that the main reason that she gave the workshop the highest capsule rating was because the instructors empowered her to take instruction risks (P-2) by providing “the opportunity to work with very expensive, technical equipment, thus enabling (her) to feel comfortable to do the same things in our classes with our students.” Teacher 6D also commented on how “there was tremendous flexibility as the professor was more than willing to answer questions and tell us interesting applications.”

Teacher 6D also expressed how the “homework” assignment caused her to reflect on how the content applied to her practice (P-3)—

*The problem sets were a bit tough, especially the ones that we didn't have the opportunity to thoroughly discuss. However, this made us think everything through, so I guess in the long run, it was to our advantage. I could relate the frustration my students sometimes feel when they do not thoroughly understand a particular concept. I guess if this is what I liked least, it wasn't all that bad. Besides, I learned something valuable.*

Teacher 10D (also 1A) commented how the “laboratory experiences, applications to state standards, recommendation of pertinent web sites, and suggestions for student activities were delivered (by the instructors) in a very open-to interjection of teacher ideas environment” (P-1). She also “enjoyed the free interchange atmosphere at all sessions … (and) enjoyed immensely the collaboration sparked by the ‘homework assignments … which contributed greatly to her long-term memory of concepts and techniques explained in class and used in the laboratory” (P-3).

D - Technician

Only Teacher 3D commented on the professional developers’ time use and delivery of information (T-1), commenting on how the teachers needed “to get up and
move around - a two hour lecture is too long without a break.” He also stated that the “lectures ran over which cut into time needed for problem sets and meals.”

Five of the eleven teachers commented about the specific skills/content taught or the resources presented within the workshop (T-2). Teacher 4D stated “the laboratory experience and the skillful description of why (they) were doing what (they) were doing in the laboratory… The lectures and laboratory experiences were well organized and skillfully presented.” Teachers 6D, 8D (also 9A), and 10D (also 1A) all commented that they appreciated the materials that were provided during the resource session on the last day.

Teacher 5D liked “the way in which the labs integrated so well with the course (and) the fact that (they) discussed the logic for what we did oftentimes after we did it rather than always before.” Teacher 8D (also 9A) disagreed with teacher 5D’s perspective, commenting that he “didn't like that the explanation of concepts tended to follow the doing of the experiment (suggesting that) more would have been gained if the concept(s) had come before (they) actually did it in the hands on part of the lab (because) during the beginning of the week (they) seemed to be sheep just following the directions not understanding what (they) were doing.”

Unfortunately, eight of the teachers indicated that the lead instructor did not have a clear understanding of their needs (T-2). Teacher 1D “(felt) lost (and) did not (always) understand.” Teacher 2D (also 10A) commented that the subject matter was “overwhelming” and the workshop provoked a “feeling of intimidation.” Teacher 9D (also 7E, 15G) felt "out of touch" and "distant from the materials” that were presented. Teacher 10D (also 1D) commented that the “ineptness (she) felt at the start of the
workshop might have been less intense if (she) had been more prepared.” Teachers 3D, 4D, 5D, 8D (also 9A), 10D (also 1A) and 11D each indicated that the individuals who did not have former training/education in (this science) were at a disadvantage and that the “prework” assigned by the instructors did not allow this population of teachers to adequately catch-up.

Specifically teachers 4D and 5D, who both had post baccalaureate coursework in (this science), stated that they did not like watching the “middle school teachers struggle with their lack of the basic (scientific) knowledge and vocabulary.” Interestingly, these same teachers who did have a more substantial subject matter background commented that even though the “technical information (was) overwhelming at times, (they) expected this workshop to be intense and to expect a lot from (them) (and) would rather (have) a challenging workshop than one that is really 'watered down' and over- simplified.”

(Teacher 11D)

Workshop E and the X-Continuum

E - Professionalism

Three of the teachers described the instructors as accessible and willing to engage the teachers as peers (P-1). Teacher 1E remarked how “the speakers were all highly qualified, enthusiastic and demonstrated a passion for science and especially (this particular science). They were all patient with our questions, wanting for us to learn and apply the basic concepts of (this science). They were open to our feedback and suggestions as the week progressed.” Teacher 2E (also 2G) liked how whenever the “instructors were given a suggestion for this course, they implemented it almost
immediately... Instructors were willing to entertain any and all questions and adapt to our needs.” Teacher 9E stated that he would “feel comfortable contacting (the instructors) in the future.”

The instructors’ openness and accessibility appears to have facilitated a collaborative environment (P-2). Teacher 1E appreciated “the chance to network within an informal setting, with the speakers, professors and other science teachers from around the state, East Coast and (other countries).” Teacher 2E (also 2G) also appreciated the opportunity to interact with the academic community and “being in the (laboratory) and interacting in an informal way with the professors and students.” Teacher 3E “enjoyed how the instructors involved everyone in the classes. (He) also enjoyed the collegial and interactive relationships the instructors shared with each other (and) how (the instructors) respect(ed) the opinions of each other even when they disagree professionally.” Teacher 5E noticed how “various viewpoints were presented on the same topic, so discussions and broader thinking could occur. There was time for participants to share ideas that were valuable even though (the teachers) were from wide backgrounds.” Teacher 9E commented how “networking with professionals and fellow teachers (was) a great experience for (him). (He would) feel comfortable contacting these people in the future.” Teacher 10E (also 9D, 15G) liked “the experiences of networking with other teachers” and commented that “it was nice to have "free" time that allowed the students (teachers) to mingle and create our own networking programs.” Only Teacher 4E expressed a different perspective, stating, “there was not much time for teachers to collaborate” (P-3).
E - Technician

Five out of the eleven teachers commented on how they enjoyed the specific skills/content that were taught, or the resources that were presented (T-2). Teacher 1E liked “the chance to learn more about … (this disciplines) program.” Teacher 4E enjoyed “the out of classroom observations” and tours. Teacher 5E learned from the (related) activities each morning. Teacher 10E’s (also 9D, 15G) found “the tours, the resources, (and) the instructors” enriching. Teacher 11E (also 10C, 8F) was “very excited to get the CD with the animations and other various resources for use in the classroom.”

As with some of the other previously described workshops, some teachers indicated that their needs were not always understood (T-2). Three of these teachers however, (1E, 2E (also 2G), and 9E) were also the teachers that commented that they felt the instructors were accessible (P-1). Teacher 1E “felt that two of the (homework) questions assigned required us to do higher level math that teachers sometimes forget how to do when they have not been using it during their career in teaching middle level students.” Teachers 2E (also 2G) and 9E suggested that the homework assignments should be reviewed in “a more structured way.” Teacher 2E (also 2G) also wanted a more fundamental overview of the content at the beginning of the workshop. Teacher 4E expressed a desire for more of an opportunity to review the homework assignment and commented how “there was not enough instances of actual application to the classroom for students.” Teacher 7E thought that the workshop should provide the teachers with “more time for practice and chances to rerun some of the activities.” Teacher 8E also thought there “could be a more intentional effort to try to make this more applicable to our individual teaching situations.”
Workshop F and the X - Continuum

F - Professionalism

Three teachers commented that the collaborative environment was what they enjoyed most about the workshop (P-2). Teacher 6F enjoyed “the ability to interact with instructors who are actively involved in research directly related to the topics explored.” Teacher 7F (who is the infamous Teacher 8C) cited “interaction among presenters” as what she liked best. Teacher 8F (also 10C, 11E) commented how “all of the instructors of the course were very knowledgeable and enthusiastic towards the content which established an environment in which the teachers also were engaged in asking questions.”

F - Technician

Eight of the ten teachers made detailed comments about the linear structure and time use of the workshop (T-1). Teacher 1F described the instructional presentation as “organized.” Teacher 2F (also 13C) described the structure of the workshop as “content driven in traditional lecture format”, “very structured”, “well-organized”, and commented how the lead instructor felt the format “shouldn't be deviated from in order for us to learn the material sequentially… so if (they) asked a question that was ‘ahead of the schedule’ (the lead instructor) usually deferred to answering it later. Although (Teacher 2F (also 13C) understood (the instructors) reasoning, this led the participant to feel less encouraged to ask questions at all.” Teacher 3F stated that “teachers were SOLEY passive recipients of information” and that “there were no ‘higher level thinking’ learning methods involved AT ALL.” “There was no structure inherent or planned in the workshop that allowed the teachers to interact and exchange or develop ideas in which to
incorporate the information presented into a curriculum. (Teacher 3F) found the workshop to be EXTREMELY linear, analytical, one-dimensional, and geared towards the status-quo dominant culture.” Teacher 4F (also 5B) described the lead instructor as “precise” and as having “an outstanding domain of the subject.” “His organization of the material was also very clear and coherent.” While Teacher 4F (also 5B) “strongly believed that the content was exceptional” she stated that there “was little opportunity to engage in discussion and to be free to ask questions.” Teacher 5F “felt that (they) had no time to interact with each other or to reflect upon (their) notes”, and explained that “there were far too many night activities which took away any time to reflect of the day's activities. Intellectually, (she) felt overloaded and wanted to spend time looking at notes to see what questions (she) still had.” She was worried that when she returned home, she would “wish that (she) had asked for clarification on some points.” Teacher 7F (Teacher 8C from the other workshop) “would have appreciated more time to reflect and digest information given about the course,” but realized “it would have been hard to add this additional time to reflect and not take away from the useful content of the course.” Teacher 9F (also 11C) realized that teachers are not the easiest people to get along with as we all have our differences, however (she commented on how the lead instructor) didn't seem to like interruptions and (at) some of our ideas and questions he would seem flustered. Not so much because he didn't know the subject matter but because he didn't know any other way to explain it or he didn't understand why someone didn't get it when he said it the first time around.” She describes the format as not having “a lot of flexibility” and thought that “questions threw him off and he didn't like to get derailed from his thought process.”
Not surprisingly, many of these teachers commented how they did not think the lead instructor understood the needs of teachers (T-2). Teacher 3F “STRONGLY recommended that (the instructors) brush up on recent pedagogical theory as well as on new findings in the field of brain research”, stating, “if this course could actually engage the teachers in a meaningful and applicable way, it would be a fantastic course.” Teacher 4F (also 5B) “did not (have) time to process, review, and prepare questions that matter to me.” Teacher 8F (also10C, 11E) thought, “it would have been beneficial to have more practical experience using some of (the distributed instructional material).”

**Workshop G and the X - Continuum**

G - Professionalism

5 of the 14 teachers viewed the instructors of this workshop as highly accessible and perceived that these instructors to treated them as peers (P-1). Teacher 1G liked “the ability to interact and converse with instructors in class and on a one to one basis during break time and during transport to other sites.” Teacher 2G (2E) commented how “the members of (this scientific group) made (the teachers) feel at home and were always willing to answer questions.” Teacher 3G noted “all the instructors were of the highest quality - knowledgeable and accessible, and appropriately demanding.” Teacher 6G (also Teacher 14B) recognized this workshop as “the very best course that (she has) ever taken for teacher development” and even though she is not (certified in this content), and will never teach a formal (course in this discipline), (she found herself) challenged to incorporate material from this class into (her) subject because it has been presented so well and in such an accessible manner.” Teacher 9G “also felt that the atmosphere was very open and everybody felt comfortable talking and asking questions without fear of
the response. (He) also felt that the instructors at the workshop did a good job presenting information in a way that was accessible to (him) as a student.”

Four of the teachers perceived the instructors as flexible and promoting a collaborative environment (P-2). Teacher 8G “liked being able to work side-by-side with some of the most respected (scientists) in the country.” Teacher 12G (also 7B) thought the “round table discussion with (experts in the field) was fascinating.” Teacher 14G “absolutely enjoyed the interactions between fellow teachers as well as the instructors of the course.” Teacher 15G (also 9D, 10E) thought “the discussions and the teamwork on the (problem solving scenario) was a great asset to the course.” Teacher 2G (also 2E) described “the instructors (as) willing to go into as much depth as the class wanted.” Teacher 10G stated, “without a doubt, every one of the instructors at this workshop provided not only essential material, but skillful facilitation, purposeful discussions, and great flexibility in response to our needs.”

G - Technician

Only Teachers 7G and 8G commented about the instructors understanding of the needs of teacher with regards to one aspect of the workshop—the pre assignment (T-2). Teacher 7G stated, “Assigning work prior to the actual class has merit” but questioned the grading policy and review techniques used by the instructors. Teacher 8G saw an improvement since the last time he attended a workshop put on by these instructors, commenting, “that the amount of pre-workshop work was more reasonable than it was two years ago.”
A reminder to the reader—

Chapter 4 allowed me to organize and present “write-ups” for each site to the reader. “These write-ups are often simply pure descriptions, but are central to the generation of insight” (Eisenhardt, 1989, p. 539).

While the intertwining of the teacher and instructor statements, field notes, and the descriptions made by the 10 trained observers creates a thick, rich description of each workshop (Creswell, 1998), an analysis of the X-Continuum is presented in Chapter 5 starting on page 110.
Chapter 5 – Analyzing Cross Case Patterns and Shaping Hypotheses

Searching for Cross-Case Patterns

Analysis of data with multiple methods helps to mitigate the researcher’s natural tendency to misinterpret information and leap to conclusions (Eisenhardt, 1989; Miles & Huberman, 1994). As stated previously, the existing literature was used to define the X and Y continua so that a cross-case comparison could be conducted on the seven workshops. The quantification of these constructs allowed me to place each workshop along scales, which could be represented visually. Due to the limited numbers of workshops and teachers enrolled in each workshop, inferential statistics would be inappropriate. Nevertheless, several patterns were identified through the coupling of descriptive statistics with the qualitative data sets. “When a pattern from one data source is corroborated by the evidence from another, the finding is stronger and better grounded” (Eisenhardt, 1989, p. 541). This corroborative process leads to triangulation, which in turn supports the creation of hypotheses and theory building (Jick, 1979; Strauss & Corbin, 1998).

Y-Continuum

The formation of the Y-Continuum was initially based on the analysis of the syllabi and course materials from the 2003 workshops, which suggested that workshop instructors utilized both experience-based/syntactic and conceptual-based/substantive pedagogical orientations. An overview of arm’s–length data from this year’s workshops presented a similar pattern: the post-workshop instructor interviews, syllabi, and course
materials all indicated that although the instructors relied predominantly on a conceptual-based/substantive orientation, they attempted to integrate experience-based/syntactic pedagogical elements into their workshops, as presented in Table 16.

**Table 16 – Overview of Arms-Length Data**

<table>
<thead>
<tr>
<th>Workshop</th>
<th>Experience-based/ Syntactic Instructional Time Indicated in Syllabus</th>
<th>Overview of Comments made in Advertising Material</th>
<th>Specific Comments made by Lead Instructor in Interviews</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Approximately 8 of the 40 instructional hours were presented as having an experience-based/syntactic pedagogical orientation</td>
<td>The participants in the workshop will create a definition of a (concept central to this discipline), collect data on (occurrences central to this discipline), and debate (concepts and occurrences central to this discipline).</td>
<td>(During the interview the instructor did not indicate that he attempted to use an Experience-based/Syntactic approach in workshop)</td>
</tr>
<tr>
<td>B</td>
<td>Scheduled 90 minutes of experience-based/syntactic pedagogy on each of the first four days; approximately 6 of the 36 instructional hours</td>
<td>Teachers will engage in hands-on activities …. as they develop resources and ideas to enhance their science programs.</td>
<td>(The teachers) break the myth that science is perfect and is done this way and they get a change to see how dirty the process is, and, …. they see how many persons are working on one topic, it’s kind of a beehive effect as opposed to Einstein popping the answer out.</td>
</tr>
<tr>
<td>C</td>
<td>Indicated that more than 9 of the 40 instructional hours were going to be experience-based/syntactic</td>
<td>The participants in the workshop will perform hands-on classroom laboratory experiments with inexpensive equipment, examine multimedia curricular material, (conduct in-depth observations), and explore the uses of (observational tools)</td>
<td>Whether it is a selection of inquiry based activities, to teach content that they already understand, or to update their content …we try to mix in content lectures… some subset of activities, demonstrations, laboratories</td>
</tr>
<tr>
<td>D</td>
<td>Scheduled approximately 11 laboratory-based hours in the 40 hour week</td>
<td>The educators will learn about contemporary research methods and models and will get firsthand experience with techniques (of this field)</td>
<td>Although what they are doing is a lot of hands on, it’s really a lot of minds on. And by combining those two, really actually seeing science in action, and understanding a lot of the basic principals that go into that, I think that spirals into their understanding of science in general and how things are done in science.</td>
</tr>
</tbody>
</table>
Although these syllabi, course descriptions, and interviews suggest that a considerable portion of each workshop would facilitate teachers in generating and establishing new knowledge claims, systematic classroom observations made by the 10 trained observers showed that instruction was almost exclusively within the conceptual-based/substantive pedagogical orientation. As described in Chapter 3, the observation protocol was based upon Magnusson, Krajcik, and Borkos’ Table 2 (1999) and uses the typical characteristics of instruction associated with a pedagogical orientation to identify
that orientation. Table 17 is an overview of the percentage of time spent in each of the pedagogical orientations; on average the instructors used a conceptual-based/substantive orientation 88% of the time, an experience-based/syntactic orientation 1% of the time, and a neutral orientation 11% of the time.

Table 17 – Continuum Y – Pedagogical Orientations Used in Workshops

<table>
<thead>
<tr>
<th>Workshops</th>
<th>Total Observers</th>
<th>Number of 15 minute observations recorded by all observers</th>
<th>Inter-rater Reliability based on intervals recorded by observers %</th>
<th>Conceptual-Based/Substantive % of time</th>
<th>Experience-Based/Syntactic % of time</th>
<th>Neutral-Activity for Activity Sake % of time</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>3</td>
<td>102</td>
<td>89</td>
<td>84</td>
<td>3</td>
<td>13</td>
</tr>
<tr>
<td>B</td>
<td>2</td>
<td>44</td>
<td>75</td>
<td>70</td>
<td>0</td>
<td>30</td>
</tr>
<tr>
<td>C</td>
<td>3</td>
<td>111</td>
<td>94</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>D</td>
<td>2</td>
<td>107</td>
<td>92</td>
<td>83</td>
<td>0</td>
<td>17</td>
</tr>
<tr>
<td>E</td>
<td>2</td>
<td>53</td>
<td>85</td>
<td>99</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>F</td>
<td>3</td>
<td>101</td>
<td>100</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>G</td>
<td>2</td>
<td>92</td>
<td>91</td>
<td>85</td>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td>Average</td>
<td>2.43</td>
<td>87</td>
<td>91</td>
<td>88</td>
<td>1</td>
<td>11</td>
</tr>
</tbody>
</table>

The teachers’ comments collected in the open-ended portion of the written evaluation instrument were also coded using these typical characteristics of instruction to further describe and identify the orientation that was implemented in each workshop. Although teachers from all of the workshops made comments on how they enjoyed the “hands-on” and experiential activities and workshop excursions, the language the teachers used to describe these occurrences usually corresponded with terms used to define the “neutral” or “activity for activity sake” pedagogical orientation. (Representative teacher comments can be seen in Table 18). When taken together, the teacher comments and observation data paint a picture of how, and to what extent, the instructors implemented pedagogical orientations in their workshops.
<table>
<thead>
<tr>
<th>Workshop</th>
<th>Representative Teacher Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Teacher 5A</td>
<td></td>
</tr>
<tr>
<td>The passive learning style of lecture-lecture-lecture, especially when the material is complex and unfamiliar, was overwhelming. . . . I realize the scope of the content is huge. The information is detailed.</td>
<td></td>
</tr>
</tbody>
</table>

Teacher 8A

There was valuable information presented. The overall workshop provided insightful information, yet it seemed more or less, like a report of what was happening in the scientific arena of (this field) through lectures mainly.

| B Teacher 2B |
| I would have to say that I came away with a decent amount of "head knowledge", and parts of it were fairly interesting intellectually, but very little that I could take back into my classroom this fall, which was overall disappointing. |

Teacher 8B

I believe most of the information that was provided in the workshop was extremely useful for science educators. There were however, some lectures that were extremely scientific, in which many of the teachers could not relate.

| C Teacher 2C |
| I liked the fact that I was exposed to such an array of facts.... I feel as though I would have benefited more from a hands on approach. |

Teacher 4C

I found there were too many elements of passive learning and not enough inquiry activities within the workshop. I wanted to be challenged and stimulated. Some of the lecturers were exciting and stimulating, others were boring and obtuse.

| D Teacher 5D |
| I felt that the lecture and lab components of the workshop were skillfully coordinated. I loved the intensity of the information. |

Teacher 6D

I could relate the frustration my students sometimes feel when they do not thoroughly understand a particular concept. I guess if this is what I liked least, it wasn't all that bad. Besides, I learned something valuable.

| E Teacher 1E |
| This workshop provided me with a great deal of knowledge on the topic of (this science). |

Teacher 2E

A vast amount of information was presented across many interests within (this discipline).

| F Teacher 2F |
| Much of the workshop was content driven in traditional lecture format. I think most of the participants wanted a great deal of content so I wouldn’t really like to see this changed. |

Teacher 5F

In this workshop, teachers were SOLEY passive recipients of information. There were no "higher level thinking" learning methods involved AT ALL - no hands-on, constructivist learning, much less anything involving the synthesis of the vast amounts of information presented.

| G Teacher 9G |
| I liked the (problem solving) scenario the best because it put the scientific information we were learning and moved it into showing the real world implication of (problem solving) and just how important (this discipline) is to the general public. |
Overall, the workshop was very similar in design to (the other workshop of this discipline). I thought that a (other) workshop would have focused more on making (physical models), and explaining systems and processes rather than just focusing on the overall methods of (this discipline).

Further analysis of another Y-continuum metric substantiates that “goals (and outcomes) of teaching science” and “the typical characteristics of the instruction” “that a teacher with a particular orientation would have” are not one and the same (Magnusson et al., 1999, p. 97).

Unlike the data collected using the observation protocol and teacher comments, which used the characteristics of instruction to define the pedagogical orientation, this portion of the summative evaluation questionnaire gauged the pedagogical orientation by way of the teachers’ experiences in the workshops. Seven items representative of each pedagogical orientation were interspersed throughout the evaluation questionnaire (Table 19). Teachers responded to these items on a 5-point Likert scale, with a “1” indicating “not at all” and a “5” indicating “to a great extent.”

Table 19 – Experience Based Questionnaire Items Used to Gauge Y – Continuum

<table>
<thead>
<tr>
<th>Experience Based</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The design of the session incorporated tasks, roles, and interactions consistent with a spirit of investigation.</td>
<td></td>
</tr>
<tr>
<td>3. Ways of establishing new scientific knowledge in the scientific field were discussed and/or explored in the workshop.</td>
<td></td>
</tr>
<tr>
<td>5. Science was portrayed as a dynamic body of knowledge continually enriched by conjecture, investigation, analysis, and/or proof of justification.</td>
<td></td>
</tr>
<tr>
<td>7. Elements of scientific abstraction (symbolic representation, theory building) were included when it was important to do so.</td>
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</tr>
<tr>
<td>9. The workshop emphasized standards of verification specific to the scientific content being presented.</td>
<td></td>
</tr>
<tr>
<td>10. Discipline specific strategies of scientific inquiry were presented and used within the context of this workshop.</td>
<td></td>
</tr>
<tr>
<td>11. The format of the workshop focused primarily on understanding scientific processes, not scientific concepts.</td>
<td></td>
</tr>
</tbody>
</table>
Table 20 – Conceptually Based Questionnaire Items Used to Gauge Y – Continuum

<table>
<thead>
<tr>
<th>Conceptually Based</th>
</tr>
</thead>
<tbody>
<tr>
<td>5. Teachers were intellectually engaged with the scientific concepts presented throughout the workshop.</td>
</tr>
<tr>
<td>6. The scientific concepts presented in the workshop were sound and appropriately explored.</td>
</tr>
<tr>
<td>12. The format of the workshop focused primarily on the clear delivery of scientific concepts, not on understanding scientific processes.</td>
</tr>
<tr>
<td>13. Discipline specific terms were presented as necessary to effectively formulating and communicating the knowledge and concepts in that scientific field.</td>
</tr>
<tr>
<td>6. The workshop placed a high priority on the clear delivery of scientific concepts.</td>
</tr>
<tr>
<td>7. The format of the workshop attempted to establish a relationship between the concepts presented in the teachers' understanding and use of these concepts.</td>
</tr>
<tr>
<td>8. The evaluation placed an emphasis on the teachers' ability to communicate/express scientific concepts learned in the course.</td>
</tr>
</tbody>
</table>

For each of the seven workshops the average responses to these two categories (conceptual-based/substantive and experienced-based/syntactic) were almost identical (Figure 5), suggesting that during the summative analysis, teachers perceived aspects of both the conceptual-based/substantive and the experienced-based/syntactic pedagogical orientations as being integrated into the fabric of the workshop. Unlike the observation protocol, where the pedagogical orientation was measured every 15 minutes, or the open-ended portion of the questionnaire, where teachers volunteered information that described the setting of the workshops, this portion of the summative evaluation necessitated that teachers react to preexisting items and reflect on the workshop as a whole. However, even if this metric prompted the teacher participants to step back and view the pedagogical orientation used in the workshop through a different lens, it seems unlikely that teachers would report such a significant gain in the use of the experienced-based/syntactic pedagogical orientation.

This divide between the measured pedagogical orientation characteristics (observations and teacher comments) and the teachers’ perceptions of what they experienced (evaluation questionnaire items) prompted me to reexamine the data collected through the evaluation questionnaire items. Further analysis revealed minimal
variance between workshops on individual evaluation items, with the exception of items s. 11 (The format of the workshop focused primarily on understanding scientific processes, not scientific concepts) and s. 12 (The format of the workshop focused primarily on the clear delivery of scientific concepts, not on understanding scientific processes).

Unlike all of the other 45 items in Section One of the Evaluation Questionnaire (Appendix A), these two items were intended to be complementary, meaning that they were only supposed to have a maximum score of “5” when added together. Teachers were instructed that the two items together represented 100% of the workshop time, and they were asked to define the workshop time-use through items s.11 and s.12. Although though this concept was carefully described to the teachers prior to the administration of the summative evaluation, teachers in three of the workshops apparently did not understand the instructions and therefore the reliability of the scores for items s.11 and s.12 is questionable (Table 21). This confusion appears to contribute some of the variance for these two items.
Table 21 - Combined Actual Scores for Items s.11 and s.12. (Supposed to be less than or equal to 5)

<table>
<thead>
<tr>
<th>Workshop</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combined Scores</td>
<td>7.80</td>
<td>4.69</td>
<td>6.62</td>
<td>4.64</td>
<td>6.25</td>
<td>4.10</td>
<td>5.15</td>
</tr>
</tbody>
</table>

Despite these problems, further scrutiny of the items seemed warranted, because they offered some promise for “controlling” for halo effects (as described in the following section). In an attempt to conduct meaningful analysis with these two items, I restructured the data by normalizing the average scores for items s.11 and s.12 so that they would add up to 5 (Table 22). The normalized scores were then divided (s.11/s.12) to create a ratio. A ratio of “1” would indicate that the teachers perceived the format of the workshop as utilizing both conceptual-based/substantive and experience-based/syntactic orientations equally. To make this outcome more understandable, “1” was subtracted from the ratio. A positive number is therefore more indicative of a conceptual-based/substantive orientation and a negative number is more indicative of an experience-based/syntactic orientation.

Table 22 - Normalized Average Scores for Items s.11 and s.12. (Sums equal 5) and s.11/s.12 ratio

<table>
<thead>
<tr>
<th>Workshop</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
</tr>
</thead>
<tbody>
<tr>
<td>s.11</td>
<td>2.37</td>
<td>2.67</td>
<td>2.15</td>
<td>2.84</td>
<td>2.53</td>
<td>2.07</td>
<td>2.39</td>
</tr>
<tr>
<td>s.12</td>
<td>2.63</td>
<td>2.33</td>
<td>2.85</td>
<td>2.16</td>
<td>2.47</td>
<td>2.93</td>
<td>2.61</td>
</tr>
<tr>
<td>Total</td>
<td>5.00</td>
<td>5.00</td>
<td>5.00</td>
<td>5.00</td>
<td>5.00</td>
<td>5.00</td>
<td>5.00</td>
</tr>
<tr>
<td>Ratio Algorithm (s.11/s.12 - 1)</td>
<td>0.10</td>
<td>-0.14</td>
<td>0.24</td>
<td>-0.32</td>
<td>-0.03</td>
<td>0.29</td>
<td>0.09</td>
</tr>
</tbody>
</table>

These adjusted numbers suggest that Workshops C and F have relatively conceptual-based/substantive orientations (greater than .1) and Workshops B and D have relatively experience-based/syntactic orientations (less than -.1).

These results align somewhat with both the observation data and the teacher comments, and although this metric gauges teachers’ experiences in the workshops and not the “characteristics of instruction,” an interesting comparison can be made with the
two sets of data. According to Table 17, Workshops C and F used conceptual-based/substantive orientations 100% of the time, more than any of the other workshops, and Workshops B and D used conceptual-based/substantive orientations less than any of the other workshops, employing a Neutral orientation more than any of the other workshops. The observation protocol did not record either Workshop B or D as using an experience-based/syntactic orientation. Consequently, I am led to interpret the B and D ratios as reports of “less substantive” orientations, but not necessarily “more syntactic.”

X-Continuum

Interviews were conducted with each of the lead instructors approximately one month after each workshop. The interviews were intended to assist in placing each of the workshops along the technician – professional continuum. For example, the instructors’ responses to the question, “How do you think the day-to-day work of science teachers differs from Ph.D. instructors, who are scientists, at the university who only have teaching responsibility (no research)?” are summarized in Table 23.

Table 23 – Sample of Instructor Comments for Question 1

<table>
<thead>
<tr>
<th>Workshop</th>
<th>Sample of Instructor Comments for Question 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>I don’t think it is a whole lot different (between K-12 teachers and college faculty), you are just teaching slightly more advanced material. (Some other departments) have teaching faculty that they do hire to do a number of their gen. ed. courses and to me that is not that much different from what you would do in high school, just slightly different material.</td>
</tr>
</tbody>
</table>
Science teachers have a pretty set and rigorous schedule, and it is pretty mapped out, 8-5 or 8-3, or what ever they do, not including the work they do in the evening. The university instructors in general have a lot less actual contact time, hours, classroom-wise, they obviously have other responsibilities because they tend to put in lots of hours too. But it’s just a lot different of a procedure. The main difference I can tell you from my experience is that teachers talk to fill up time, and not to say what they are doing is not important, but there is a lot more classroom management skills that are necessary, and since they have so many hours and no prep time--their prep has to be done during the summer and from their experience in the past, it’s more about, I don’t want to say baby sitting, but they have to fill time.

Professional development for a teacher involves them studying teaching techniques, theory, as well as content, but professional development for (scientists) involves going to a colloquium and listing to the latest results coming out (about current research in my field). And I’m sure there is probably some overlap, like I probably need to do some teaching techniques professional development and they probably need to do content development, which is why they come to us, but I would say that the ratio is probably reverse for those two.

I think it is very different, because if you look at the population that we have to deal with, compared with the population that the science teachers have to deal with, I think there is a very different challenge right there. From that point of view that it is very different, the mindset that the science teachers in K-12 have to have is different than our mindset (Speaking as an instructor). So, I think we (instructors) have gotten beyond the phase that K-12 teacher have to deal with discipline in the students.

Supposedly we are dealing with a select subset at the college level. They have to pass through some filter to be taught so it should by that process be easier than dealing with the total spectrum of students in the public or K-12 school.

I’m just an (instructor)…… I don’t have any idea what [a teacher’s] job description is. I mean I’ve never read a job description of a high school teacher.

The amount of preparation is fantastically different. The load on a high school or secondary science teacher is much, much bigger than it is on a university instructor, and even in some semesters when I have taught four or five courses, my schedule is still much lighter than [a high school teacher’s]. The high school teaching, day-to-day work, is extremely arduous, and actually I think there is a problem with our system in how we do things: it’s too much for individuals to be doing.

A panel of 25 graduate students from a university Educational Leadership Program (K-12 administrators, K-12 practicing teachers, and university instructors) was asked to assess the instructors’ responses for the three most relevant interview questions along a five-point Likert scale. The scale ranged from 1 (Professional development workshop environment recognizes teachers as technicians) to 5 (Professional development workshop environment recognizes teachers as professionals). Because the interviews contained varying degrees of information and detail, the graduate students were also asked to rank their “confidence level” using a second Likert Scale that ranged from 1 (Not at all confident) to 5 (Confident to a great extent).
Although “teacher as professional” and “teacher as technician” are well-established terms in the field of educational leadership, I anticipated that the graduate students’ placement of workshop instructors on the Likert scales would still be partially dependent upon their personal interpretation of the terms. Therefore the \textit{a priori} codes were reviewed and discussed with the graduate students for approximately 15 minutes to ensure that they would use similar conceptions of “professional” and “technician” as defined by this study.

Of the 25 graduate students, 22 had teaching experience at the K-12 level (mean 9.5 years): seventeen were currently K-12 teachers, and five were currently administrators (mean of 7.5 years of administrative experience). Three of the graduate students had never taught in a K-12 setting.

The graduate students recorded consistently high confidence levels in their ability to place the workshop instructors on the X-continuum, averaging 3.73 – 3.85 (S.D. = .67 – 1.07) for each of the seven workshops. The consistency with which the different groups (administrators, teachers, and graduate students) rated the instructors along the X-continuum suggests the reliability of this metric (Table 24). Administrators consistently scored comments farther toward the “Teacher as Professional” end of the continuum.

| Table 24 – Reliability of Expert Perspectives |
| Workshop | A  | B  | C  | D  | E  | F  | G  | Average |
| Admin (n=5) | 3.4 | 3.4 | 3.0 | 2.8 | 4.1 | 3.6 | 3.6 | 3.4 |
| Teachers (n=17) | 3.1 | 2.9 | 1.9 | 2.2 | 4.0 | 3.3 | 3.3 | 3.0 |
| GA (n=3) | 3.2 | 2.9 | 1.9 | 2.4 | 4.0 | 3.1 | 3.1 | 3.0 |
| All (n=25) | 3.2 | 3.2 | 2.1 | 2.5 | 4.0 | 3.3 | 3.3 | 3.1 |

The 87 teachers who attended the summer workshops were asked to rate the culture of the seven workshops. Participant teachers used a Likert Scale from 1 (Not at
All) to 5 (To a Great Extent) to rate their responses. As defined in Chapter 3, eight
evaluation questionnaire items based on the a priori constructs defined the “Culture”
construct. The items were scored so that an overall synthesis rating of “1” would indicate
that the teachers perceived themselves as being treated as technicians by the professional
development providers. An overall synthesis rating of “5” would indicate that the
teachers perceived themselves as being treated as professionals.

Table 25 – Culture Rating of Participant Teachers

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Rating along X-Cont.</td>
<td>4.5</td>
<td>4.2</td>
<td>4.2</td>
<td>4.8</td>
<td>4.9</td>
<td>3.6</td>
<td>5.0</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>1.30</td>
<td>.89</td>
<td>.89</td>
<td>.67</td>
<td>1.20</td>
<td>1.4</td>
<td>0</td>
</tr>
</tbody>
</table>

Both the participant and expert perspectives of the workshop instructors’ views of
teachers as professionals/technicians are shown in Figure 6. It should be noted, as
indicated in Chapter 3, the teacher participant data collected using the Horizon
Questionnaire appears to be skewed towards the “teacher as professional” end of the
continuum. It appears that this offset between the two data sets shown in Figure 6 is
caused by the Culture portion of the Horizon Questionnaire steering responses towards
the “teacher as professional” end of the continuum, but this conjecture cannot be stated
with certainty. This offset, which consistently places participant perspectives
approximately one Likert point above the expert perspectives, suggests similar trends
along the X continuum between these two metrics. And because different groups
analyzed the same workshops, this trend ascribes both validity and reliability to the
professional/technician construct.
Possible Halo Effects

Analysis of the evaluation questionnaire items suggests that some of these descriptive data trends used to describe both the X and Y continua may be attributed to halo effects. Although the design of the study and the data sets do not allow for the isolation and control of this effect, some additional figures may help the reader evaluate this influence.

Because the constructs in question were developed separately using the items from the evaluation questionnaire, synthesis ratings were derived in two ways: First, by averaging individual items of the five different constructs, and second, by averaging the synthesis ratings of the five different constructs. As demonstrated in Figure 7, the values of the two measures are almost identical.
To access the impact of a halo effect on the Y-continuum, I created a new overall rating by averaging all the items of the five constructs found within Section One of the evaluation questionnaire (Appendix A) less the “science content” items. This allowed me to better compare, and not overlap, the synthesis rating with the experience-based/syntactic and conceptual-based/substantive constructs, indicating that there might be a relationship between how teachers responded to this construct and their overall feeling towards the workshop.
Similarly, in order to evaluate the possible halo effect on the Y continuum, an average of all the synthesis ratings minus the culture synthesis was derived. Although the impact of the halo effect can be vaguely perceived, there is significantly more variation between the synthesis rating (minus the culture construct) and the culture construct.

![Figure 9 - Possible Halo Effect - Continuum X](image)

**Figure 9 - Possible Halo Effect - Continuum X**

<table>
<thead>
<tr>
<th>Workshop</th>
<th>Average - All Synthesis minus Culture</th>
<th>Synthesis Rating: Culture</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1.2</td>
<td>3.5</td>
</tr>
<tr>
<td>B</td>
<td>1.8</td>
<td>3.0</td>
</tr>
<tr>
<td>C</td>
<td>2.0</td>
<td>3.5</td>
</tr>
<tr>
<td>D</td>
<td>2.5</td>
<td>4.0</td>
</tr>
<tr>
<td>E</td>
<td>3.0</td>
<td>3.5</td>
</tr>
<tr>
<td>F</td>
<td>3.5</td>
<td>4.0</td>
</tr>
<tr>
<td>G</td>
<td>4.0</td>
<td>4.5</td>
</tr>
</tbody>
</table>

**Shaping Hypotheses**

Ultimately, “shaping hypotheses in theory building research involves measuring constructs and verifying relationships” (Eisenhardt, 1989, p. 543). Compared to hypothesis-testing research, theory building research is often perceived as judgmental because the researcher cannot dispassionately point to inferential statistics. Therefore the researcher must accurately display both the evidence and procedures, allowing the reader to make an informed decision when judging the strength and consistency of the relationships within and across cases.

Having described the professional development contexts of the seven workshops (using within-case data and through the identification of cross-case patterns), I can begin
to explore how university-based professional development contexts impact teachers’ understanding of the nature of science. Because these observations revealed that the pedagogical orientations (Y-continuum) used in the seven workshops were very similar, my hypothesis shaping will be based primarily on the impact of the X–continuum (professional <-> technician) on the teachers’ understanding of the nature of science.

Before shaping a hypothesis, the nature of science construct needs be “sharpened” through a two-step process that involves refining the definition of each aspect of the construct and building evidence that measures how the construct was impacted in each case (Eisenhardt, 1989, p. 541). The instrument used in this study, the VNOS Change Survey (VCS) (Appendix E), was derived from VNOS-B and VNOS-C (Lederman et al., 2002). It should be noted that unlike the original VNOS-B and VNOS-C, this study’s VCS was modified to evaluate how teachers’ views about the nature of science changed as a result of attending one of the seven workshops. For example, Question 1 from the original VNOS- Form C read,

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)?

This question was modified and divided into two separate questions on the VCS. The first portion of the question now reads--

1. As a result of attending this workshop, has your definition of “science” changed in any way?

   - Yes
   - No

If your definition has changed, please explain how.
If a teacher’s understanding of the nature of science had changed as a result of attending the workshop, he or she was asked to respond by selecting the appropriate “yes” button and elaborating in the text box on the changes, using examples from the workshop whenever possible.

Lederman et al’s original surveys were again reviewed in order to gain perspective on the variety of responses. The survey texts were coded using 14 aspects of the nature of science, as developed through the NOS literature and validated after surveying and interviewing nine NOS experts with doctoral degrees in science education, or history or philosophy of science. The 14 NOS aspects are used to code and define responses from both the VNOS-B and VNOS-C instrument (Lederman et al., 2002).

The “face and content validity” of the VNOS-B and VNOS-C have been “determined repeatedly” and the results from the various VNOS studies “support a high confidence level in the validity of the VNOS for assessing the NOS understandings of a wide variety of respondents” (Lederman et al., 2002, p. 517).

Tables 26 and 27 illuminate were designed to summarize emergent relationship between the Nature of Science and the professional development context, (Eisenhardt, 1989; Miles & Huberman, 1994). Table 26 is a quantitative overview of how teachers’ understandings of the NOS changed as a function of attending a workshop. The “Number ‘Yes’ Responses” column is the total number of times that teachers reported that they had experienced a change in their understanding of the nature of science, by workshop. The “Teachers in Workshop” is the number of teachers enrolled in that particular workshop. The “Number ’Yes’ Teachers” column reports how many different teachers selected “yes” for at least one question. The “Ratio ‘Yes’ to Teachers” (or
VNOS Ratio), is the total number of times that teachers reported that they had experienced a change in their understanding of the nature of science, by workshop, divided by the number of teachers in that workshop. The rightmost column shows that workshops varied greatly in the percent of teacher participants who reported any change, from 10 – 64%.

Table 26 - Number of Teachers Who Reported Changes in their Views of NOS

<table>
<thead>
<tr>
<th>Workshop</th>
<th># of Teachers Responding “Yes” to Questions 1-8</th>
<th>Number “Yes”</th>
<th>Number Teachers</th>
<th>“Yes” Teachers</th>
<th>Ratio “Yes” to Teachers</th>
<th>% Teachers Reporting Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>5 3 2 2 1 1 1 2</td>
<td>18</td>
<td>10</td>
<td>6</td>
<td>1.8</td>
<td>60</td>
</tr>
<tr>
<td>B</td>
<td>2 0 0 1 1 0 1 1</td>
<td>4</td>
<td>16</td>
<td>4</td>
<td>.25</td>
<td>25</td>
</tr>
<tr>
<td>C</td>
<td>1 0 3 1 4 1 3 2</td>
<td>17</td>
<td>14</td>
<td>9</td>
<td>1.2</td>
<td>25</td>
</tr>
<tr>
<td>D</td>
<td>2 0 1 1 1 1 0 1</td>
<td>14</td>
<td>11</td>
<td>5</td>
<td>1.3</td>
<td>45</td>
</tr>
<tr>
<td>E</td>
<td>2 4 1 3 2 3 4 2</td>
<td>22</td>
<td>12</td>
<td>6</td>
<td>1.8</td>
<td>50</td>
</tr>
<tr>
<td>F</td>
<td>1 1 1 1 0 0 0 0</td>
<td>4</td>
<td>10</td>
<td>1</td>
<td>.4</td>
<td>10</td>
</tr>
<tr>
<td>G</td>
<td>1 3 1 3 3 1 3 5</td>
<td>21</td>
<td>14</td>
<td>8</td>
<td>1.5</td>
<td>57</td>
</tr>
<tr>
<td>Total</td>
<td>14 11 9 11 13 8 14 19</td>
<td>98</td>
<td>68</td>
<td>42</td>
<td>2.3</td>
<td>57</td>
</tr>
</tbody>
</table>

A comparison of the 1) VNOS Ratio and 2) Percentage of Teachers Who Report Change columns to the workshops placement along the X-continuum reveals a pattern: In Workshops B and F, which were located farthest from the “teacher as professional” end of the X continuum, a lower percentage of teachers reported having experienced changes in their VNOS. Also, a higher percentage of teachers in the G, E, D, and A workshops, the workshops placed closest to the “teacher as professional” end of the X-continuum, experienced significant changes in their VNOS. Although these data do not explain “how” or “why” teachers in different workshops experienced different levels of change in their VNOS (Yin, 2003), they do suggest that there is a relationship between whether instructors treat teachers as technicians or professionals in a workshop, and the changes that these teachers experienced in their views on the nature of science.
Table 26 does not assume a “restrictive one-to-one correspondence between an item on the questionnaire and a target NOS aspect” (Lederman et al., 2002, p. 512). The quantitative data in Table 27 provides an overview of how teachers’ understanding of the NOS was impacted by particular workshops, and coupled with other data collected during this study, allows me to hypothesize why specific professional development contexts might have been better suited to promote change in the teachers’ VNOS. Table 27 tabulates the aspects of the nature of science in which teachers reported change; the 6 (of 14) codes in which two or more teachers experienced change are listed.

In an effort to make this hypothesis-building portion more significant, the “more informed” teacher views on the nature of science are in bold in Table 27 (Lederman et al., 2002). Although “more naïve” views suggest change in the teachers’ views of the nature of science, they are not included in the subsequent discussion because they do not clearly identify how or why teachers experienced meaningful change.

**Table 27 - Aspects of NOS that Teachers Reported Changed**

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>5</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>1</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>5</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>5</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>6</td>
<td>1</td>
<td>1</td>
<td>8</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>
Changes in Teachers’ Understanding of the NOS – Within Workshops

The teachers in Workshops A, C, and D reported changes in certain aspects of their views of the nature of science that were not experienced by teachers in other workshops. Some patterns have been identified and explanations proposed to explain why teachers experienced changes within these specific environments. A brief definition of each of the codes is provided, followed by a short explanation of how and why teachers in a specific workshop experienced change.

Code 2 – The Scientific Method

Lederman et al (2002) cite several seminal works that have debunked the “belief that there is a recipe-like stepwise procedure that all scientists follow when they do science.” Although scientists “observe, compare, measure, test, speculate, hypothesize, create ideas and conceptual tools, and construct theories and explanations”, there is “no single sequence of activities” that defines the scientific method (pgs. 501-502).

Workshop C and Code 2

Teachers 11C, 13C and 3C commented that explicit NOS content presented in the C workshop confronted their misconception that a particular and straightforward scientific method is universal in the sciences. 3C was amazed at the “time and effort that goes into getting the information we know today.” 13C indicated that this workshop redirected her perspective about how “science and how the scientific method works in ‘real life.’” 11C indicated that what “changed was (my) knowledge of (this science) and how scientists in their various fields approach the questions and experiments that are very
different than other fields… (This) workshop has given (me) an insight into this process.”

**Workshop D and Code 2**

In workshop D, the one workshop in which teachers did not record any substantial changes in their understanding of the empirical nature of science (Code 1), several teachers did indicate that their perceptions about the scientific method did change. When the lead instructor was asked how his workshop would promote such a change in the teachers VNOS, he responded:

*There is nothing so mysterious about doing science once the methods are understood and established. So, of course the other part of that also is that the fact that the hands on, what you are doing, is discussed and explained in a very understandable way. Although what they are doing is a lot of hands on, it’s really a lot of minds on. And by combining those two, really actually seeing science in action, and understanding a lot of the basic principals that go into that, I think that spirals into their understanding of science in general and how things are done in science.*

Unlike most of the other workshops, teachers in Workshop D spent a considerable amount of time engaged in laboratory activities. Through these experiences two middle school teachers, 3D and 9D, reported gaining a better understanding of the complexities of methods used in the laboratory. For teacher 3D, it “became more obvious how many steps and details can be involved in even simple experiments.” For teacher 9D the workshop “created a better sense of … the processes that "build up" to the science.”

**Code 6 – The Tentative Nature of Science**

“Scientific knowledge, although reliable and durable, is never absolute or certain… Scientific claims change as new evidence, made possible through advance in
thinking and technology, is brought to bear on these claims, and as extant evidence is reinterpreted in the light of new theoretical advances, changes in the cultural and social spheres, or shifts in the directions or established research programs” (Lederman et al., 2002, p. 502).

**Workshop A and Code 6**

Teacher 5A gained “a much better understanding of why science is an ongoing investigation.” The workshop demonstrated that it is “healthy and normal” for “two scientists to draw two different conclusions from the same set of data” and to engage in “active disagreement and revision of thought… Science is not frozen in books, but lives through inquiry and debate.” He responded that “now (he) knows (changes in science are) less an issue of personal bias on the part of scientists than interpretation of data by competent thinkers and gathering evidence… textbooks give no notion of the rapidity of changing theories and the impact of new data.”

Teacher 6A commented that this workshop had taught her that “science allows overlap of disciplines, and nothing is ever really set in stone. Ideas change and theories are revised… Science is an ever-changing genre.” She explains that this change was prompted by “the opportunity to interact with scientists who are currently active in science (and by) gaining insight on areas of science that I am unfamiliar with.”

In the open-ended portion of the evaluation, seven of the ten teachers indicated that they really enjoyed the interactions between scientists during the discussion formats, some citing that they especially enjoyed when the scientists disagreed. Each of the five teachers who stated that there were too many lectures also stated how they enjoyed the interactive, interdisciplinary nature of the workshop. Teachers appeared to experience
change in their understanding of the tentative nature of science due to sessions that were organized around *interactions between scientists*.

**Code 8 – Scientific Theories**

“Scientific theories are well-established, highly substantiated, internally consistent systems of explanations. Theories serve to explain large sets of seemingly unrelated observations in more than one field of investigation… Theories have a major role in generating research problems and guiding future investigations. Scientific theories are often based on a set of assumptions or axioms and posit the existence of nonobservable entities… Only indirect evidence can be used to support theories and establish their validity” (Lederman et al., 2002, p. 500).

**Workshop C and Code 8**

Four of the teachers in Workshop C indicated that their understanding of the dynamic nature of theories was impacted by the instructors’ explicit presentation of the NOS. 2C learned that “theories are always changing based on the data and material uncovered to support, define or confirm thought.” 6C realized that “theories may change after unexpected or different results come from the experiments”, and “scientists would have to alter a theory once different results are obtained.” She reported that any change that occurred was due to what she had learned about “advancements in data collection” within this field. 5C also explained, “Seeing first hand how new developments in technology can change the theories of prior scientists helped me to see the connection
that… science is truly constantly changing.” Teacher 4C realized that with “the discovery of new facts (within this discipline), theories and ideas are always changing.”

An Overview of Changes in Teachers’ Understanding of the NOS – Within Workshops

In review, teachers in Workshop C appear to have experienced changes in their understanding of the scientific method (Code 2) and the nature of scientific theories (Code 5) because of the instructors’ explicit presentation of these aspects of the NOS. Teachers in Workshop A experienced changes in their understanding of the tentative nature of science (Code 6) because the workshop was structured in a way that promoted interaction between instructors, and because the lead instructor explicitly modeled the tentative nature of this discipline through the curriculum. Teachers in Workshop D learned about the scientific method through their experiences in the daily laboratory activities.

Changes in Teachers’ Understanding of the NOS – Across Workshops

Teachers experienced changes in their understanding of the nature of science as defined by Codes 1, 11, and 14 in four or more of the workshops. These changes appear to have been prompted by characteristics shared across these workshops. As with the previous section, a brief definition of each of these codes is provided, followed by a short proposed explanation of how and why teachers in a specific workshop experienced change. At the end of each section, a brief hypothesis is presented to explain how and why workshops’ contexts promoted change in the teachers understanding of the nature of science.
Code 1 - The Empirical NOS

“Sooner or later, the validity of scientific claims is settled by referring to observations of phenomena” (American Association for the Advancement of Science, 1990, p. 4). The scientists in each workshop spent considerable time explaining to teachers how their observations are filtered through “perceptual apparatus and/or intricate instrumentation, interpreted from within elaborate theoretical frameworks, and almost always mediated by a host of assumptions that underlie the functioning of scientific instruments” (Lederman et al., 2002, p. 499). Two or more teachers in all of the workshops except D indicated that they experienced a change in their empirical understanding of the NOS. In each of the workshops teachers identified certain attributes or approaches used in the workshops that changed their understanding of the empirical NOS. During the post workshop interview, the instructors were also asked to identify the attributes of their workshop that they thought would impact teachers’ understanding of the NOS. On overview of both teacher participant and instructor comments in presented in table 28.

Table 28 – Overview of Code 1 – Empirical Nature of Science

<table>
<thead>
<tr>
<th>Workshop</th>
<th>Specific Comments made by Lead Instructor</th>
<th>Overview of Teacher Comments</th>
<th>Proposed Explanation for Changes in Teachers’ Understanding of NOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td><em>I think the thing what is unique about our workshop and (this) field compared to any one of these other fields is that we are more interdisciplinary, and (this field) absolutely covers the map scientifically, so to me, the thing that the teachers would hopefully get an appreciation from would be that to really make progress in this field you have to pull bits and pieces out of many</em></td>
<td>Four teachers, one of whom responded in numerous questions, indicated their understanding of the empirical NOS changed as a result of attending this workshop. Three of the teachers commented specifically on how this professional development experience taught them how</td>
<td>The workshop instructors continuously modeled the interdisciplinary nature of this discipline-- Several teachers commented in the open-ended portion of the evaluation questionnaire on how “the organization and planning included presenters from many areas showing</td>
</tr>
</tbody>
</table>
different fields and somehow synthesize them into a self-consistent theory and the real thing that they should walk away with is that it is an extraordinary ambitious undertaking and that people spend their lives just trying to learn enough just trying to be up to speed to understand what the problems are in these different fields.

B Many of the teachers (who have) come to (this university) as student in the education department, (their) involvement with a researcher has been the person in front of their 300 person lecture hall or they have been at some place that is smaller where there is not much research going on, so I think my workshop brings them closer... they get that chance to be on a first name basis (with scientists).

As phenomena are examined more closely by more experimenters or with the use of new instruments or technologies, often new data is uncovered that does not fit into the currently accepted theories, and that requires the theories to be modified, revised, expanded, or rejected (16B).

I can see now that a scientist can ... solve a problem by using nanoscale technology that would achieve a desired result that macro-scale science could not (7B).

There are a number of thought experiments, prior to or in addition to, the experiment that are often of even greater importance than the physical act of experimenting (10C).

Teachers expressed how the interactions with the workshop instructors demonstrated to them that (this discipline) is an “empirically based”, and that experiments are necessary for the development of interdisciplinary nature of science” (7A).

10 of the 16 teachers commented positively in the open-ended portion of the evaluation questionnaire about their experiences in this workshop with technology. These comments seem to be closely related to the four teachers who indicated that they had experienced a change in their understanding of the empirical NOS.

C So (what) I did was, OK, I gave them my research talk, which is this is what I now understand about this (topic) but then I spent an hour saying that in order to get to that research talk well first I had to write a proposal to get (observation) time, then I had to go (collect data), then I came back and I had the data on my computer and it took me a year to (analyze the data), you know this is the output, then I had to interpret that, and that actually goes to one of the other questions, which is “do scientists use there creativity and imagination?”, well, um, if you look with what we have to work with, it’s a database of numbers—it’s nine columns and 14,000 rows, and out of that you have to say, “well,(this phenomena is different than we originally thought), and this is why”, so I think that talk was one of the things that instigated it.

There are a number of thought experiments, prior to or in addition to, the experiment that are often of even greater importance than the physical act of experimenting (10C).

Two of the teachers in the C workshop indicated that they experienced a change in their understanding of the empirical NOS because this workshop “helped clarify that observation is a valid form of experiment” (8C).

Both participants indicated that they thought the change that they experienced in the NOS occurred because the workshop coordinators continually reiterated and demonstrated this aspect of the NOS in their lectures.

E We have a practical problem in physics and math we solve (regularly), and I think that when we present it in that format and paint the scenarios out as far as (this) problem that they can appreciate the applicability of it and

Teachers 7E and 11E both stated that the workshop instructors demonstrated to them that (this discipline) is an “empirically based”, and that experiments are necessary for the development of
therefore that changes perhaps there paradigm of what they thought about the science.

Teacher 11E also recognized that physics and chemistry are really the foundation of (this discipline) and (this discipline) is based upon the experimental and observation findings of these scientists.

"Because of the individuals that we had the privilege of interacting with, by means of lectures and demonstrations, I believe that I would question facts presented to me more intensely. I also will question myself and feel compelled to gather more information prior to forming an opinion because of this experience."

Well I guess part of it would be that we do work very hard to bring people in to give guest lectures, you know I do this all the time. We try to bring in people who are actively doing science, and you know, I think just being able to talk to a few of these people and see the types of issues that they deal with every day, and being able to question them where something isn’t making sense. The person is right there and you can ask them questions about why they did what they did or why this is important in the broad scheme of things, that makes it possible.

(Scientists in this discipline) face a tough task as (they do not) actually have a hands on approach to something that is (hard to observe). So it (was) interesting to see how they overcome this issue... The kind of work cosmologists do is a little bit different than the rest of the scientific community. It is not as precise... and I had a hard time understanding that a 30-40% error was good (9F).

Not Certain

Only one teacher indicated that her understanding of the empirical nature of science was impacted by this workshop.

F

In biology (he is) used to seeing a much more "exact" science in which through experimentation I can get one result and continue to get that same result over and over again. In (this discipline) one can experiment and get one result and perform the same experimentation the same way and get another due to the almost infinite amount of variables present …, which one can't account for” (9G).

"'Tinkering' with (this type of) model is (more) like experimenting… than (he) realized” (8G).

G

"In biology (he is) used to seeing a much more "exact" science in which through experimentation I can get one result and continue to get that same result over and over again. In (this discipline) one can experiment and get one result and perform the same experimentation the same way and get another due to the almost infinite amount of variables present …, which one can't account for” (9G).

"'Tinkering' with (this type of) model is (more) like experimenting… than (he) realized” (8G).

An Overview of Code 1

As indicated through Table 28, a variety of factors impacted the teachers understanding of the empirical NOS. First, teachers and instructors acknowledged that the university scientists attempted to model the empirical nature of science through the
curriculum, discussions, and activities. Several of the instructors and teachers also indicated that the empirical nature of science was explicitly discussed within these workshops. Finally, both teachers and instructors attributed this change to teachers’ interactions with university scientists and within a research environment.

Code 11 – The Creative and Imaginative Nature of Science

“Science is empirical. The development of scientific knowledge involves making observations of nature. Nonetheless, generating scientific knowledge also involves human imagination and creativity. Science, contrary to common belief, is not lifeless, entirely rational, and orderly activity. Science involves the invention of explanations and theoretical entities, which requires a great deal of creativity on the part of scientists” (Lederman et al., 2002, p. 500).

Workshop A and Code 11

Three middle school teachers (2A, 4A, 6A) experienced change in their understanding of the creative and imaginative NOS. Teacher 6A specifically commented on how she “now realizes the extent of creativity and integration required during the planning of exploration missions. (She) also better understands how scientists within the same discipline interpret data differently” (6A).

The teachers in this workshop appear to indicate that their changes about the creative and imaginative NOS was prompted by the flexible and collaborative environment fostered in this workshop by the instructors (P-2). For example, in the open-ended portion of the evaluation questionnaire, Teacher 4A indicated that she “hadn’t realized” the amount of interaction and sharing/exchanging ideas that occurs
between colleagues within the sciences. Teacher 7A commented that “there was a warm sense of congeniality” even when “different scientists had different interpretations … and different conclusions … from similar data.”

**Workshop D and Code 11**

Four middle school teachers and one high school teacher expressed that this workshop changed how they view the creative and imaginative aspects of the scientific process. Teacher 1D came to understand that “there could not be any concept of experimentation without imagination and creativity.” Teacher 3D experienced similar changes in his understanding of the NOS and continued to say that if scientists do not incorporate imagination and creativity into their lab procedures they run the risk of “not exploring new avenues of discovery.” Teacher 9D realized that as in other areas of life, in a “different light, perspectives and ideas can change… Scientist must use and apply these different angles to further knowledge.”

6D, the one high school teacher who reported change in her views of this aspect of the NOS, commented that the workshop helped her differentiate between the creative and imaginative aspects of scientific methodology—“Planning and design probably involve the most creative processes, as scientists need to question what is already known and think of ways to expand that knowledge. Collection of data is just that. After collection of data, analysis of results again involves creative thinking to take the newfound knowledge further or to revisit the drawing board.”

None of these teachers explicitly explain in the VNOS questionnaire how this workshop changed this aspect of their understanding of the NOS. 1D and 6D, however,
both gave Workshop D high ranks because it facilitated “communication with other teachers” and because of the “tremendous flexibility of the professor who was more than willing to answer questions” (P-2). Teacher 6D also indicated that the main reason that she gave the workshop the highest capsule rating was because the instructors empowered her to take instructional risks (P-2).

**Workshop E and Code 11**

Teacher 5E wrote, “We were able to hear three different views on (an area of research) using some similar data. I think it changed my thinking that everyone would use the data in the same way… I saw some wildly imaginative research this week and I don't think that I believed scientists were that creative.” In regard to the professional climate created in this workshop, 5E remarked in the open-ended questionnaire, “Various viewpoints were presented on the same topic so that discussions and broader thinking could occur. There was (also) time for participants to share ideas which was valuable even though (the participants had) different backgrounds.”

For similar reasons, teacher 3E “now believe(s) that … humans do the best they can applying the knowledge they have in an effort to approximate, recreate, and explain what is likely at given times in an effort to better understand.” He also remarked in the open-ended questionnaire that the instructors “involved everyone in the classes,” “shared collegial and interactive relationships… with each other,” and enjoyed “how they respected each others opinions… even when they disagreed professionally.”

Teacher 12E remarked that the workshop changed her perceptions of science because she saw how the scientists “create models (of things that they cannot see but
exist). (These) scientists have imagination and creativity (that enables them to) discover things.” 12E commented specifically how she appreciated how the workshop instructors encouraged her to participate and treating her as a professional, despite the fact that she was different from the other teachers.

**Workshop G and Code 11**

Six of the teachers made comments about how Workshop G had changed their perceptions of the creative and imaginative nature of science. 1G, 5G, and 8G commented on how scientists “use their creativity and expertise to better interpret the results that they get from their experiments / computer models” (5G) and that they had “more appreciation for the delicate balance between human judgment and computer models” (8G). This workshop also demonstrated to 8G “that (these scientists) definitely have to use imagination along with scientific data to visualize what may happen.”

14G and 12G came to understand how “scientists use creativity to develop plans of attack to answer questions (especially) in the planning and design phase” (14G). The more “scientists use their creativity/imagination in the planning and design of the experiments” (12G), “the more creative (the scientist will be) with exploring new areas, revisiting old ones, (and) the more beneficial the data will be” (14G).

Most of these teachers also made comments about being treated as professionals by the scientists-- 1G, a high school teacher, commented how he appreciated “having instructors that are experts in their fields and being able to converse and interact with them on a personal basis.” Teacher 8G, a middle school teacher “liked being able to work side-by-side with some of the most respected (scientists) in the country.” Teacher
14G “absolutely enjoyed the interactions between fellow teachers as well as the instructors of the course.”

Overview of Code 11

In the initial analysis of the quantitative data, a correlation appeared between workshop teachers’ understanding of creative and imaginative NOS and the placement of the workshops on the X continuum. Further analysis suggested that the position of the workshop on the X dimension alone does not explain why teachers in workshops were more or less likely to experience change in their creative and imaginative understanding of the nature of science. The subsequent discussion of findings is intended to reflect the iterative data collection and analysis process and identify a possible covariate that affected this outcome.

Throughout data analysis I looked carefully for other attributes of the workshop beyond the a priori X and Y dimensions that might have potentially impacted the teachers’ views of the nature of science. A summative analysis of the three most frequently cited codes (Code 1, 11, 15) revealed that middle school and high school teachers from all the workshops responded in almost equal proportions to codes 1 and 14, but not to Code11: 11 out of the 15 teachers who indicated that they had experienced a change in their views about the creative or imaginative NOS taught at the middle school level. It should also be noted that there was only one middle school teacher in the B workshop, and only two middle school teachers in the F workshop, the one teacher in those two workshops who reported a change in his views of the creative and imaginative nature of science was an 11th and 12th grade science teacher. Of the four workshops (A, D, E, G) in which numerous teachers were recorded to have experienced changes in their
views of the creative and imaginative NOS, the middle school-high schoolteacher proportions were almost equal, with the exception of the E workshop, which had 7 middle school, 2 high school, and 2 “other” teachers.

The evaluation questionnaire did not require that the teachers disclose the amount of science course work they had completed, and of the eleven middle school teachers, only one indicated that she was taking these graduate credits to pursue certification or licensure. Some of the other middle school teachers indicated through their evaluation comments that the science content was beyond their background. For example, one stated, “There were a few times when a couple of presentations got a little beyond my conceptual understanding but that is to be expected being that I am elementary certified and not a science specialist.”

My working assumption is that as a group, the middle school educators had weaker science backgrounds than the high school educators and that their preinstructional views of the NOS were less likely to recognize the creative aspects of science.

**Code 14 - Social and Cultural Components of Science**

This code is based on the premise that, “Science is a human enterprise practiced in the context of a large culture and its practitioners are the product of that culture. Science, it follows, affects and is affected by the various elements and intellectual spheres of the culture in which it is embedded” (Lederman et al., 2002, p. 501).

**Workshop A and Code 14**

Two of the teachers experienced change in their social and cultural understanding of the nature of science. Although teacher 6A suggested in the evaluation questionnaire
that the workshop “may have been more helpful (if it had) more group discussions” and that the “lecture format limited interaction and reflection”, she commented in the VNOS questionnaire that “science as more collaborative and interdisciplinary than it was when I was in college” (6A), and that the workshop did a good job of integrating “speakers of varied backgrounds” (evaluation questionnaire).

Teacher 5A indicated in the evaluation questionnaire that “being able to ask questions of the scientists and present questions that arise in the classroom, and get intelligent, thoughtful answers, was great.”

**Workshop C and Code 14**

Three of the teachers, 7C, 9C, and 4C reported that they previously thought that science is “universal” but they now realize that how scientists interpret their findings can be impacted by their agendas, perspectives, and “one's social and cultural values will have some effect on what is believed to be true or the way in which science should focus and move.”

None of these three teachers gave enough of a response in the VNOS questionnaire to suggest how the workshop changed their understanding of this aspect of the NOS.

**Workshop D and Code 14**

An increase in content knowledge coupled with a few discussions specifically on ethics appears to have impacted teachers’ understanding of the social and cultural components of science. Teacher 3D remarked that “the whole concept of ethics was not
as focused for (him as) before nor did (he) see all the various ways that ethics were
involved in (this field) before reading the text and taking this course.” Through the
various discussions teacher 7D came to ‘realize that money drives science, especially in
(this field).” She also “learned that social and political values greatly affect science…
and determine what science can be conducted.” Teacher 6D reflected on how
“acceptance of scientific discoveries is socially and culturally driven” but “the
universality of science” is not changed by science-- “what is, is.” Teacher 1D agreed
with 6D’s statement about the acceptance of science, but added a caveat stating, “How
science is accepted in (Asia) is different then how science is accepted in the United
States. Science is questioned here (in the USA) whereas in many Asian nations the
concept of science is always a good thing.” This additional comment was prompted by a
conversation on the second day that about cloning policies in different nations.

Workshop G and Code 14

Three of the teachers commented that this “workshop clearly showed how science
and the needs of a society are related in a meaningful way” (3G). Teachers as noted
“This course showed how the WAY that science is REPORTED to the public can be
greatly affected by the social and cultural values of the population” (6G). The teachers
“realized that (modeling) involves much more than just making (reports)-- It involves not
only safety and convenience issues, but politics and money as well” (14G).

Overview of Code 14

For Code 14, teachers did not clearly describe what aspects of the workshops
impacted their understanding of this aspect of the NOS. However, as teacher 5A
commented, “I used to think that science was, or attempted to be, completely free of cultural norms. But now I believe that's not true, and science reacts to time the same way as other things. Even now, we are locked into assumptions that are societal that we can look back and realize our oversights.”
Chapter 6 – Reaching Closure by Enfolding Literature and Exploring Implications

Implications of the X-Continuum

Most of the seminal studies (Abd-El-Khalick, 2001; Abd-El-Khalick, Bell, & Lederman, 1998; Abd-El-Khalick & Lederman, 2000a, 2000b; Akerson & Abd-El-Khalick, 2000; Bell, Lederman, & Abd-El-Khalick, 2000; Lederman, Schwartz, Abd-El-Khalick, & Bell, 2001) and in-depth literature reviews (Abd-El-Khalick & Lederman, 2000a; Lederman, 1992) on the NOS in the last 15 years have been conducted by the same research group. These studies have concluded that an explicit/reflective teaching approach is most effective in promoting adequate conceptions of the NOS among both “prospective and practicing teachers” (Akerson & Abd-El-Khalick, 2000, p. 297). It should be noted, however, that all of these studies were conducted in the context of preservice elementary and secondary science methods courses. The process of generalizing these findings to practicing teachers appears to have occurred only in literature reviews and is not clearly substantiated in published research reports.

Recognizing that most NOS studies have been conducted in the context of preservice teacher education, Akerson et. al. (2000) argue that based on both research on situated cognition (Brown et al., 1989) and the transfer of learning (Lanier & Little, 1986), science content courses, as opposed to educational courses, would probably provide the best environment for improving teachers’ views of NOS. However, even after learning their content knowledge through traditional science content courses offered through colleges of the sciences, college students still tend to enter teacher education programs with uninformed views of the nature of science (Akerson & Abd-El-Khalick, 2000; Lederman & Latz, 1995). Although these researchers recognize that “science
methods courses might not have been the optimal context for developing preservice science teachers’ NOS views,” they were the “available context” in which these numerous studies have been conducted (Akerson & Abd-El-Khalick, 2000).

The literature concurs with Akerson and Abd-El-Khalick’s conclusion: Science learning results from activities and ideas that are accepted by the scientific community and that challenge a learner’s prior conceptions (Bransford, Brown, & Cocking, 2002; Driver et al., 1994; National Research Council, 1996a; Posner, Strike, Hewson, & Gertzog, 1982). However, before science educators are able to identify the best contexts for instruction (Brown et al., 1989), they must clearly define and understand the population with whom they are working.

The literature also suggests that teacher learning is largely dependent upon the career stage of the individual teacher (Fessler, 1995). The explicit/reflective approach used to teach the nature of science might be better suited to the preservice teacher population. For example, in the prior mentioned studies of the NOS, learning contexts were typically structured in ways that treat the preservice population as technicians:

First, the student’s role is limited due to a perceived lack of required skills and knowledge (Hawley & Valli, 1999; Little, 1993). Second, the learning environments modeled in these studies have a tendency to clearly delineate roles: The instructor provides the information that facilitates the preservice teacher in the adoption of this new material (Tillema & Imants, 1995, p. 147). Third, time use in these environments is an “objective variable, an instrumental, organizational condition that can be managerially manipulated in order to foster the implementation of educational changes whose purpose and desirability have been determined elsewhere” (Hargreaves, 1994, p. 95; Schön,
Finally, because prespecified skills and content are taught and resources presented in these educational settings, the preservice teachers are often not encouraged to self-assess their subject matter knowledge (NOS) and pedagogical content knowledge, implying that the instructors are better suited in defining what preservice teachers need to learn in order to close the gap between science education goals and performance standards (Borko & Putnam, 1995; Hawley & Valli, 1999; Tillema & Imants, 1995).

Preservice teachers are hopefully in the process of becoming professionals. Inservice teachers are regarded as professionals. Even though apprenticed and experienced professionals share a common body of knowledge, preservice and inservice teachers are in distinct career stages and different professional development strategies should be used with these different populations (Fessler, 1995; Randi & Zeichner, 2004). Along these lines, Dewey forewarned educators about assigning the teaching of theory exclusively to teacher preparation programs and the development of practice exclusively to the inservice teacher population, and he recognized that preservice and inservice teachers would come to professional development experiences with vastly different prior knowledge and experiences (Dewey, 1904; Randi & Zeichner, 2004).

Professionals, such as inservice teachers, learn best in settings where they have the opportunity to interact and engage in an environment where opportunities for learning are promoted by participation and work with other professionals, rather than “structured by master tradesmen in the form of directions for accomplishing specific tasks” (Lave & Wenger, 1991; Randi & Zeichner, 2004, p. 207; Schön, 1991). The findings of my dissertation concur and suggest that the learning facilitated by teacher-scientist interactions is also very important: Inservice teachers are more likely to experience
change in certain aspects of their views about the nature of science in professional
development contexts where they are treated as professionals. Workshop instructors that
fostered collaborative flexible environments and treated teachers as professionals appear
to have had greater impacts on teachers’ learning about the creative, imaginative, social,
and cultural understanding of the NOS.

By demonstrating that inservice teachers’ understandings of the nature of science
are impacted by how they are treated in a professional development context, either as
professionals or technicians, this study suggests that science teacher professional
development should involve initiating inservice teachers into the ideas and practices of
the scientific community (Driver et al., 1994, p. 6).

Teaching is a learning profession and professional development contexts need to
assign teachers a certain amount of responsibility for their own learning (Darling-
Hammond & Sykes, 1999; Loucks-Horsley et al., 1998; National Research Council,
1996a). “Without opportunities to take responsibility for their own learning, and without
the need to seek knowledge beyond their own schools and classrooms, teachers may not
have sufficient opportunities in the ‘flow of information’ to develop the aptitude, as
individuals and as a profession” (Randi & Zeichner, 2004, p. 182). The work of science
teaching cannot be accomplished without teacher learning, and teachers of science learn
about scientific communities when scientist invite them to engage in the context of
scientific practice (Ball & Cohen, 1999).

Unfortunately, numerous state and federal policies do not support science teachers
as they seek to achieve these ends. Many of these policies push schools and universities
to design professional development offerings that attempt to generate social capital in
order to improve the school as an organization and do not enrich the individual science teacher (Leslie & Brinkman, 1988; Smylie & Weaver-Hart, 1999). For example, school-based professional development programs are often unable to create real world or everyday settings that will effectively promote scientific knowledge, which tends to be discipline specific and generated in laboratories, field settings, and other environments that are unlike the typical public school.

The knowledge of educational theories and methods taught to teachers in these school-based professional development environments, while essential, plays a secondary role in the content qualifications of the science teacher and his/her understanding of pedagogical content knowledge (Shulman, 1986b). In order to improve classroom teaching, individual teachers’ knowledge of subject matter and pedagogical content knowledge must improve (Borko, 2004).

As the previously mentioned NOS studies verify, the importance of the university’s role in providing subject matter training and content knowledge preparation for preservice K-12 science teachers is well documented (Monk, 1994; National Research Council: Committee on Science and Mathematics Teacher Preparation, 2001). However, once preservice teachers gain certification, the university typically ceases to be a viable route for providing strong subject matter instruction, despite research that shows that the money spent on subject-specific PD for inservice teachers has more of an impact on student learning than any other district expenditure (National Research Council: Committee on Science and Mathematics Teacher Preparation, 2001; Odden & Archibald, 2001).
Scientific knowledge is rapidly changing and K – 12 science teachers and curricula require continual renewal if they are to be accessible and relevant to students’ lives (Lederman, 1998; National Research Council, 1996a, p. 59; Schwab & Brandwein, 1962). The university is uniquely situated to provide contexts through which inservice teachers can realize what Lederman refers to as the “social and cultural embeddedness of scientific knowledge” (2002, p. 501). “Science, as a human enterprise is practiced in the context of a larger culture and its practitioners are the product of that culture” (Lederman et al., 2002, p. 501). Together, university scientists and science educators can aim to create and provide professional development programs for inservice teachers that articulate and/or model the nature of science (Joseph, 2000; Little, 1993; National Research Council, 1996a; National Research Council: Committee on Science and Mathematics Teacher Preparation, 2001; Schwab, 1964).

This role of university faculty in promoting meaningful educational change through inservice teacher professional development has long been theorized, but seldom modeled (Fullan, 1995, 2001); cordial relations and clear mutual goals shared between discipline specialists, such as university scientists and the K – 12 staff development communities, have not existed, and dysfunctional relationships between K-12 schools and the university over the past century have inhibited the solidification of these meaningful professional development partnerships (Dewey, 1902; Marx, Blumenfeld, & Krajcik, 1998). With rare exceptions, “cultural apprenticeships” (Brown et al., 1989, p. 40) specific to the sciences have not been commonly experienced by K – 12 science teachers (Driver et al., 1994). A strong professional development community is an important contributor to instructional improvement and school reform (Borko, 2004).
Even though the teachers in this study “generally welcomed the opportunity to discuss ideas and materials related to their work, and conversations in (these) professional development settings (were) easily fostered” (Borko, 2004, p. 7), many of the university scientists did not actively attempt to understand the pedagogical knowledge and pedagogical content knowledge that these teachers possess. University scientists, university science educators, and K-12 science teachers need to incorporate each other’s expertise in professional development offerings. This collaboration between scientists and science educators can be achieved when all parties agree to and share ownership of the professional development process and acknowledge the professional knowledge that each other possess (Darling-Hammond & McLaughlin, 1995; Little, 1993).

Implications of the Y-Continuum

In my formal evaluation of these seven workshops, the lead instructors and I met together after the interview process for a two hour working lunch to discuss how the best practices of professional development for teachers of science cited in the literature, and how some of my preliminary research findings about the teacher as “professional” versus “technician” might be applied to their future practice. When these best practices and research findings were explicitly shared, most of the lead instructors stated that they desired to incorporate these ideas into their future practice. This anecdote raises the questions of whether the instructors’ willingness to embrace new practices connotes their understanding of these best practices and research findings. Furthermore, if instructors do understand these best practices, how will this knowledge impact their future practice? (Lanier & Little, 1986).
What instructors know and what/how they teach are not always the same (Bransford et al., 2002; Lave, 1988). Each of these instructors had a Ph.D. in their respective scientific discipline and practiced scientific inquiry in a way that is consistent with what I will refer to as the NRC’s first definition of inquiry: “The diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work” (National Research Council, 1996a, p. 23). However, as demonstrated through the light of the classroom observations and teacher comments, the instructors’ pedagogical orientations were not reflective of what I will refer to as the NRC’s second definition of inquiry-- “the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world” (National Research Council, 1996a, p. 23).

This disconnect between the instructors’ professional practice and their pedagogical orientations can be explained in two ways. First, scientists and science educators do not conceptualize inquiry in the same way: The scientist is primarily interested in advancing knowledge, in developing new hypotheses and trying to verify them. Educators also are interested in the subject matter and processes of science, but their primary interest is in how that knowledge becomes part of the student’s experience (Dewey, 1902; Shulman, 1986a).

Second, these expert scientists, even though they have a high level of content knowledge, lack pedagogical knowledge and pedagogical content knowledge. Comprehensive inquiry, as defined by science educators, requires that both the substantive and syntactic aspects of the nature of science be included in classroom instruction (National Academy of Sciences., 1998; Schwab & Brandwein, 1962).
Scientists involved in education need to demonstrate how inquiry results in scientific knowledge (NRC, 2001), and more specifically, scientists involved in professional development need to explore and understand children and teachers’ scientific understandings and conceptual frameworks (Posner et al., 1982). A scientist’s ability to achieve these ends is partially dependent upon his/her pedagogical knowledge and pedagogical content knowledge.

The disconnect between the scientists’ and science educators’ operational definitions of inquiry is evident in a statement cited earlier. When asked what goals he had established for teachers who attended his workshop, the lead instructor for Workshop F responded,

*We want to certainly give them the content necessary to teach their students at the level recommended by the National Science Standards. And I think that we do that fairly effectively. Those science standards, which you’ve probably read, are fairly terse. They don’t actually flesh things out. I think that is one of the goals, to get it so that they can teach their kids at that level. And how can we facilitate teachers in achieving those goals, well, you witnessed how you do it. We teach them the content... Well, when they come to my workshop, I’m sorry, I don’t want to be unpleasant, but they don’t actually do science. They aren’t at the level where they could do that effectively.*

Scientists can benefit from their interactions with experienced science educators by gaining enhanced understanding of science content, fuller understanding of the complexities of teaching science at any level, and a more comprehensive understanding of inquiry-based science teaching and its value (Shulman, 1986b; Thompson, Collins, Metzgar, Joeston, & Shepherd, 2002). Additional benefits for the scientists may include improved public relations, competitiveness for grants, and a natural avenue for undergraduate and graduate recruitment in the sciences.
Through these collaborative interactions, teachers also come to a better understanding of the inquiry processes that these scientists experience in their professional practice, and can ultimately help teachers translate inquiry into their classrooms: an inquiry that includes “deep science content and process knowledge” (Jeanpierre, Oberhauser, & Freeman, 2005, p. 1 (preprint version)).

Conclusion

Like his predecessors, Einstein was unable to mathematically account for certain cosmological occurrences. He longed to explain the inner workings of the physical universe with an elegant yet comprehensive “theory of everything.” This inability to account for certain variables frustrated and ultimately caused him to derive the “cosmological constant,” which he later referred to as his “greatest blunder,” in order to accurately model the expansion of our universe.

Today we know that Einstein’s “greatest blunder” is actually one of his greatest achievements-- The cosmological constant is not a cosmological fudge factor, but appears to effectively account for dark matter. Einstein’s willingness to explore and theorize despite an incomplete understanding of the universe paid large dividends for today’s scientists who continue to attempt to demystify the cosmos.

Social scientists also study environments where it is difficult to account for all variables, and at times may yearn for an elegant yet comprehensive “theory of everything” that explains the inner workings of educational settings. Although studies in naturalistic contexts cannot account for all variables and therefore run the risk of
generating more questions than answers, it is within these contexts that our oversights can create new insights and prove most valuable in defining the “universe” that we study.

Because this study was conducted in the context of one-week university-based workshops, whose limitations are often cited in the literature (Loucks-Horsley et al., 1998; National Research Council, 1996a, 1996b; National Research Council: Committee on Science and Mathematics Teacher Preparation, 2001), further studies should be conducted to explore if these findings hold true in environments where best practices are used to guide the design, implementation, and delivery of the professional development programs (Loucks-Horsley et al., 1998; National Research Council, 1996a, 1996b). And while these conclusions cannot be simply generalized to all professional development contexts, they provide insights and uncover patterns that might exist in other inservice teacher education contexts.
Works Cited


2004 Workshops for Science Educators Evaluation

PLEASE COMPLETE ALL FIELDS

Teacher Name: _____________________________________

Workshop:

Instructions

Please complete all items. Please note that "Teachers" refers to you your fellow schoolteachers, and "Instructors" refers to the workshop presenters.

Grades you currently teach:

☐ 5th
☐ 6th
☐ 7th
☐ 8th
☐ 9th
☐ 10th
☐ 11th
☐ 12th

List courses/subjects that you currently teach: ______________________________________________
____________________________________________________________________________________

Section One

In this section, you are asked to rate a number of key indicators, from 1 (not at all) to 5 (to a great extent). Please select "Don't know" when there is not enough evidence for you to make a judgment, or "Not applicable" (N/A) when you consider the indicator inappropriate given the purpose and context of the session.
I. Design

A. Rating Key Indicators

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Design of the session NOT at all reflective of best practice professional development

Design of the session extremely reflective of best practice professional development
## II. Implementation

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1. Formal presentation(s) included in the session were carried out effectively.

   The instructor(s) effectively modeled questioning strategies that are likely to enhance the development of conceptual understanding.

2. The instructor(s)' background, experience, and/or expertise enhanced the quality of the session.

3. The instructor(s)' management style enhanced the quality of the session.

4. Teachers were intellectually engaged with the scientific concepts presented throughout the workshop.

   The pace of the session was appropriate for the purposes of the professional development and the needs of teachers.

   Extent of "sense-making" about classroom practice was appropriate for the purposes of the session and the needs of adult learners.

### B. Synthesis Rating

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Implementation of the session NOT at all reflective of best practice professional development

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Implementation of the session extremely reflective of best practice professional development

- 3 - 159
III. Science Content

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<th>To a great extent</th>
<th>Don't know</th>
<th>N/A</th>
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<tbody>
<tr>
<td>1. Science content was appropriate for the purposes of the professional development session and the backgrounds of the teachers.</td>
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<tr>
<td>2. The scientific concepts presented in the workshop were sound and appropriately explored.</td>
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<tr>
<td>Ways of establishing new scientific knowledge in the scientific field were discussed and/or explored in the workshop.</td>
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<tr>
<td>4. Instructor(s) displayed an understanding of the science concepts (e.g., in their dialogue with teachers). Science was portrayed as a dynamic body of knowledge continually enriched by conjecture, investigation, analysis, and/or proof of justification.</td>
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<td>5. Depth and breadth of attention to science content was appropriate for the purposes of the session and teachers' needs. Elements of scientific abstraction (symbolic representation, theory building) were included when it was important to do so. Appropriate connections were made to other areas of science, to other disciplines, and/or to real-world contexts. The workshop emphasized standards of verification specific to the scientific content being presented. Discipline specific strategies of scientific inquiry were presented and used within the context of this workshop. The format of the workshop focused primarily on understanding scientific processes, not scientific concepts. The format of the workshop focused primarily on the clear delivery of scientific concepts, not on understanding scientific processes. Discipline specific terms were presented as necessary to effectively formulating and communicating the knowledge and concepts in that scientific field. The science content presented in the course was consistent with the state and federal standards used to define the course goals/objectives.</td>
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<thead>
<tr>
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<th>Science content of the workshop</th>
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### IV. Exploring Pedagogy/Instructional Materials

#### A. Rating Key Indicators

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<tbody>
<tr>
<td>1.</td>
<td>Depth and breath of attention to student thinking/learning were appropriate for the purposes of the workshop and teachers' needs.</td>
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<td>2.</td>
<td>Depth and breadth of attention to classroom strategies were appropriate for the purposes of the workshop and teachers' needs.</td>
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<td>3.</td>
<td>Depth and breadth of attention to instructional materials intended for classroom use were appropriate for the purposes of the workshop and teachers' needs.</td>
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<td>4.</td>
<td>Instructor(s) displayed an understanding of pedagogical concepts (e.g., in their dialogue with teachers).</td>
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<td>5.</td>
<td>Teachers were intellectually engaged with important ideas relevant to classroom practice.</td>
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<td>6.</td>
<td>The workshop placed a high priority on the clear delivery of scientific concepts.</td>
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<td>7.</td>
<td>The format of the workshop attempted to establish a relationship between the concepts presented in the teachers' understanding and use of these concepts.</td>
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<td>8.</td>
<td>The evaluation placed an emphasis on the teachers' ability to communicate/express scientific concepts learned in the course.</td>
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V. Culture of the Professional Development Workshop

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<th>To a great extent</th>
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<tr>
<td>1. Active participation of the teachers was encouraged and valued throughout the workshop.</td>
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<td>2. Teachers' experiences, ideas, and contributions were solicited and incorporated into the workshop's format.</td>
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<td>3. Collegial interactions among participants were encouraged.</td>
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<td>4. Interactions reflected collaborative working relationships between facilitator(s) and participants.</td>
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<td>5. Instructors encouraged participants to generate ideas, questions conjectures, and propositions.</td>
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<td>6. Instructors created an environment in which teachers were willing to share ideas and take intellectual risks. Intellectual rigor, constructive criticism, and the challenging of ideas were evident in the interactions between instructors and teachers.</td>
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<td>7. This workshop would appeal to teachers of diverse ethnicity, race, age, and gender.</td>
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<td>Culture of the Professional Development workshop NOT at all reflective of best practice professional development</td>
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<td>Culture of the Professional Development workshop extremely reflective of best practice professional development</td>
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VI. Capsule Description of the Quality of the Professional Development - In this final rating, select the capsule description that best characterizes your workshop. Please provide a brief rationale for your final capsule description of the workshop in the space provided.

1 **Level 1:** There was little opportunity for teachers to engage with important ideas. The workshop is unlikely to enhance the capacity of teachers to provide high quality science education. The primary approach of the workshop is best described as (select one below):

   ○ **Passive Learning** - Teachers were passive recipients of information.
   ○ **Inaccessible** - Material was presented in a way that was inaccessible to or inappropriate for many teachers.
   ○ **Activity for Activity's Sake** - Participants were involved in hands-on activities or other individual or group work, but it appeared to be activity for its own sake.

2 **Level 2:** Contained some elements of effective practice in professional development, but there were serious problems in the design, content, and/or implementation. For example, the content may have been presented in a way that would reinforce misconceptions or the pace may have been too rapid for meaningful teacher engagement. Overall, the workshop is limited in its likelihood to enhance the capacity of most teachers to provide high quality science education.

3 **Level 3:** Professional development was purposeful and at times effective, but there were some weaknesses in the design, content, or implementation of the workshop. For example, teachers’ expertise may not have been well-utilized; or teachers may not have been given sufficient opportunity to reflect on what they were learning. Overall, the workshop is somewhat limited in its likelihood to enhance the capacity of teachers to provide high quality science education.

4 **Level 4:** Facilitation was skillful and teachers were engaged in purposeful work (e.g., investigations, discussions). The instructor(s) implemented the professional development workshop well. Teachers' contributions were valued, although adaptations of content or format in response to teachers' needs and interests may have been limited. The workshop is likely to enhance the capacity of most teachers to provide high quality science education.

5 **Level 5:** Facilitation was skillful, and teachers were highly engaged in purposeful work (e.g., investigations, discussions). The workshop was artfully implemented, with flexibility and responsiveness to teacher needs and interests. The workshop is highly likely to enhance the capacity of teachers to provide high quality science education.
Please provide your rationale for the capsule rating (Please limit your response to this box.)

VII Open-Ended Responses

What did you like best about the workshop?

What did you like least about the workshop?
Section Two

A. How did you learn of this program? (Check all that apply)

☐ 1. Flyer or brochure
☐ 2. Advertisement
☐ 3. Web
☐ 4. Phone call by University
☐ 5. Recommended by colleague
☐ 6. Other

B. How far in advance would you like to receive information for an upcoming program?

○ 1. 1-2 months
○ 2. 3-4 months
○ 3. 5-6 months
○ 4. 7-8 months
○ 5. 9-10 months
○ 6. 11-12 or more months

C. Why did you attend this program? (Check all that apply)

☐ 1. To meet a mandatory employer requirement
☐ 2. To maintain a professional designation, certification, or license
☐ 3. To pursue a professional designation, certification, or license
☐ 4. To earn ACT 48 credits (or to fulfill state mandated professional development requirements)
☐ 5. To earn graduate credits (for a degree)
☐ 6. To earn graduate credits (for a salary increase)
☐ 7. To meet my own professional development interests
☐ 8. To network with people who have similar interests
☐ 9. Other: ___________________________
Please select the response that best describes your overall assessment of the organization and coordination of the workshop you attended.

<table>
<thead>
<tr>
<th></th>
<th>Not at all</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>To a great extent</th>
<th>Don't know</th>
<th>N/A</th>
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<tbody>
<tr>
<td>1. The promotion materials and web site accurately described the workshop.</td>
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<td>2. Information about the workshop application and registration processes were easy to follow.</td>
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<td>3. My application acceptance information was received in a timely manner following my submission.</td>
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<td>4. My workshop credit registration instructions were received in a timely manner.</td>
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<td>5. The workshop acknowledgment information was helpful.</td>
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<td>6. The pre-course materials and assignment were received in time for me to review and to complete them before the start of the course.</td>
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<td>7. The residence hall check-in and check-out processes were handled effectively.</td>
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<td>8. The residence hall staff was courteous and helpful.</td>
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<td>9. The classroom and lab facilities were suitable for the workshop.</td>
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<td>10. The Conferences and Institutes staff was available during the week to provide information about University processes and logistics.</td>
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<td>11. The time of the workshop (month, week, hour) was convenient.</td>
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<td>12. The informal functions (dinner or picnics) were important elements in the workshop schedule.</td>
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<td>13. The quality of food and service during the informal functions were well executed.</td>
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<td>14. The evaluation (of the workshops) was conducted professionally.</td>
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</table>
II. Ongoing Professional Development

A. What types of science education professional development most interest you? (Check all that apply)

- Interactive computer
- Expert moderated bulletin boards
- Video conferences
- Audio conferences
- In-person instruction
- Print-based study guides
- Field study trips
- Facilitated research projects
- In-service in my district
- College credit
- Non-credit
- Weekday schedule
- Weekend schedule
- 1-day workshops
- One-week workshops
- Other

III. Workshop Activities

A. Indicate the major activities of teachers in this session. (Check all that apply)

1. Listened to formal presentation by
   - Session presenter/instructor
   - Teachers
2. Engaged in discussion/seminars/reporting-out structured as
   - Entire group led by presenter/instructor
   - Entire group led by teacher
   - Subset of the entire group
3. Engaged in problem solving/investigation focusing on disciplinary content, pedagogy, and/or reform issues
4. Read about disciplinary content, pedagogy, or reform issues
5. Wrote about disciplinary content, pedagogy, or reform
IV. Overall Rating of Session

A. Select the response that best describes how this session will impact your teaching practice:

○ 1. Your ability to identify and understand important ideas of science
○ 2. Your understanding of science as a dynamic body of knowledge generated and enriched by investigation
○ 3. Your understanding of how students learn
○ 4. Your ability to plan/provide high quality science classroom instruction
○ 5. Your ability to use the designated instructional materials to develop students' conceptual understanding
○ 6. Your self-confidence as a science instructor
○ 7. Your networking among teachers with regards to science instruction

Portions of this protocol were developed by Horizon Research, Inc. for the core evaluation of NSF's Local Systemic Change through Teacher Enhancement program
Observation Form for the 2004 Workshops for Science Educators – IRB # 18493

Directions: Place numerical overview and brief explanation of choice in the appropriate space.

<table>
<thead>
<tr>
<th>Course:</th>
<th>Pedagogy (Numerical overview):</th>
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<tbody>
<tr>
<td>Date:</td>
<td>1) Process 6) Discovery</td>
</tr>
<tr>
<td>Observer:</td>
<td>2) Academic Rigor 7) Project-Based Science</td>
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<tr>
<td>Number of students:</td>
<td>3) Didactic 8) Guided Inquiry</td>
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<td></td>
<td>4) Student Conceptions 9) Independent Inquiry</td>
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<td></td>
<td>5) Activity Driven (Magnusson, Krajcik, and Borko, 1999)</td>
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</tbody>
</table>

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<thead>
<tr>
<th>Pedagogy at that moment:</th>
<th>Pedagogy in context:</th>
<th>Instructor/Place</th>
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<tbody>
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<td>Time</td>
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Appendix C – Instructions for the Time-Based Pedagogical Orientation Instrument
Instructions for the use of the Time-Based Pedagogical Orientation Instrument:

While the purpose of these training sessions is to help you distinguish and understand the differences between the pedagogical orientations, our time together is limited. The accuracy of this instrument is dependent upon your ability to successfully categorize the pedagogical orientations utilized the workshop(s) you attend. We therefore recommend that you memorize and are familiar with the 9 pedagogic orientations listed below prior to the second training session.

1. At the beginning of each day, fill in the following information on the top of the observation form: a) course name, b) date, c) your name (observer), and d) number of students (including yourself).
2. Instructors and locations commonly change in each workshop. Please indicate these changes and the time that they occur in the rightmost column labeled “Instructors and Locations.”
3. Every ___ minutes use the left column, labeled “Pedagogy at that Moment”, to record the (one) number corresponding to the specific pedagogical orientation being used in the classroom. Please note that many activities might be occurring in a classroom at any given moment. Therefore, as observers you will view the classroom as a single unit. Record the (one) pedagogical orientation that best describes that unit. We define “at that moment” not as an instantaneous occurrence, but as an overview of the last 2 minutes of classroom occurrences.
4. In the space provided in the left column write a brief justification of your choice of pedagogical orientation. Please note that a proper justification requires that you understand and remember each of the pedagogical orientations.
5. In the center column, write down a more in-depth description of what has occurred at the designated ___-minute intervals. Please use the Pedagogical Orientations to describe what has occurred in the classroom during these intervals. In this column, you are not limited to one orientation. Please be as descriptive as possible.

<table>
<thead>
<tr>
<th>Pedagogical Orientation</th>
<th>Key Words</th>
<th>Definition</th>
<th>Example/Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Process</td>
<td>Precise progression</td>
<td>Teacher introduces students to the thinking processes employed by scientists to acquire new knowledge. Students engage in activities to develop thinking process and integrated thinking skills.</td>
<td></td>
</tr>
<tr>
<td>2 Academic Rigor</td>
<td>Verification of concept with activity</td>
<td>Laboratory work and/or demonstrations are used to verify science concepts by demonstrating the relationship between particular concepts and phenomena. There should be a clear connection of laboratory work and/or demonstrations to concepts and phenomena.</td>
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</tr>
<tr>
<td>3 Didactic</td>
<td>Presentation of “facts” and information</td>
<td>The teacher presents information, generally through lecture or discussion, and questions directed to students are to hold them accountable for knowing the facts produced by science.</td>
<td></td>
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<tr>
<td>4 Student Conceptions</td>
<td>1) Query student views 2) Establish claims</td>
<td>Students are pressed for their views about the world and consider the adequacy of alternative explanations. The teacher facilitates discussion and debate necessary to establish valid knowledge claims.</td>
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<tr>
<td>5 Activity Driven</td>
<td>Activity precedes concept of phenomena.</td>
<td>Students participate in “hands-on” activities used for verification or discovery. The chosen activities may not be conceptually coherent if teachers do not understand the purpose of particular activities and as a consequence omit or inappropriately modify critical aspects of them.</td>
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<tr>
<td>6 Discovery</td>
<td>Student-Centered</td>
<td>Students explore the natural world following their own interests and discover patterns of how the world works during their explorations.</td>
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<tr>
<td>7 Project-Based Science</td>
<td>Driving theme. Ongoing activities. Artifacts.</td>
<td>Teacher and student activity centers around a “driving” theme that organizes concepts and principles and drives activities within a topic of study. Through investigation, students develop a series of artifacts (products) that reflect their emerging understandings.</td>
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<tr>
<td>8 Guided Inquiry -</td>
<td>Community-Centered/Social Construction. Formal scientific questions.</td>
<td>The teacher and students participate in defining and investigating problems, determining patterns, inventing and testing explanations, and evaluating the utility and validity of their data and the adequacy of their conclusions. The teacher scaffolds students’ efforts to use the material and intellectual tools of science, toward their independent use of them.</td>
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</tr>
<tr>
<td>9 Independent Inquiry</td>
<td>Investigation-Centered/ Bound individual or groups. Formal scientific question</td>
<td>The teacher supports students in defining and investigating problems, drawing conclusions, and assessing the validity of knowledge from their conclusions.</td>
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Appendix D – Interview Protocol
Interview Protocol

1) How do you think the day-to-day work of (science) teachers differs from Ph.D. instructors (scientists) at the university who only have teaching responsibility (no research)?

2) A teacher calls you and asks you to explain your expectations of the participants who attend your workshop. How would you respond? (Please note if there are differences between your workshops.)

3) What goals have you established for teachers who attend your workshop? How do you facilitate the teachers in achieving these goals? (Please note if there are differences between your workshops.)

4) Imagine that the S. Institute calls you, stating that they are impressed your workshop and they have decided to allocate $20,000 to help you further develop it. You can spend the money any way that you would like. How would you spend it? (Please note if there are differences between your workshops.)

5) Please look at these questions from the Views of the Nature of Science Survey that I administered to the teachers at the end of the workshop. (Questions 1, 5, and 8 – these are the questions that teachers responded most often to) If a teacher answered “yes” to having experienced change in their understanding of the NOS in your workshop, what about your workshop (what aspect of your workshop) do you believe caused this change?

6) There is a big debate among science education researchers. Some evidence indicates inservice teachers need to be taught the nature of science explicitly: for example, there needs to be an explicit curriculum that defines science, theory, experiments, or how these processes occur…Others state that scientists learn implicitly about the nature of science by doing science – they are not presented with an explicit curriculum of science – therefore teachers should also learn about science in this way. How would you characterize your workshop: as implicitly or explicitly instructing teachers about the nature of science?
Appendix E – 2004 Workshops for Science Educators VNOS Change Survey
2004 Workshops for Science Educators VNOS Change Survey

Teacher Name: ____________________________________

Workshop:

This questionnaire is designed to evaluate how your views about the nature of science have changed as a result of attending a Penn State Workshop for Science Educators. If your response to a question has changed as a result of attending this workshop, please check the “yes” button and elaborate in the text box on the changes that have occurred, using examples from the workshop whenever possible. If your response to a question has NOT changed as a result of attending this workshop, please check the “no” button and answer “no change” in the text box.

1. As a result of attending this workshop, has your definition of “science” changed in any way?
   ○ Yes
   ○ No

If your definition has changed, please explain how.
2. As a result of attending this workshop, has your perspective changed in any way on what makes science (or a scientific discipline such as physics or biology) different from other disciplines of inquiry, such as religion or philosophy?
   ○ Yes
   ○ No

   If your perspective has changed, please explain how.

3. As a result of attending this workshop, has your definition of an “experiment” changed in any way?
   ○ Yes
   ○ No

   If your definition has changed, please explain how.
4. As a result of attending this workshop, has your response to the following question changed in any way: *Does the development of scientific knowledge require experiments?*

   ○ Yes Please respond to question 4, NOT the italicized question.
   ○ No

   If your response to the question has changed, please explain how it has changed.

5. As a result of attending this workshop, has your response to the following question(s) changed in any way: After scientists have developed a scientific theory (e.g., atomic theory, evolution theory), does the theory ever change? If you believe that scientific theories do change: (a) Explain why theories change? (b) Explain why we bother to learn scientific theories.

   ○ Yes Respond to question 5, not the italicized question.
   ○ No

   If your response to the question(s) has changed, please explain how it has changed.
6. As a result of attending this workshop, has your response to the following question changed in any way: Is there a difference between a scientific theory and a scientific law?

○ Yes    Respond to question 6, not the italicized question.

○ No

If your response to the question has changed, please explain how it has changed.

7. As a result of attending this workshop, has your response to the following question changed in any way: 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. Do you believe that science reflects social and cultural values, or do you believe that science is universal?

○ Yes    Respond to question 7, not the italicized question.

○ No

If your response to the question has changed, please explain how it has changed.
8. As a result of attending this workshop, has your response to the following question changed in any way: 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?

a. If yes, then at which 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.

b. If you believe that scientists do not use imagination and creativity, please explain why.

○ Yes  **Respond to question 8, not the italicized question.**

○ No

If your response to the question has changed, please explain how it has changed.
Dwight Andrew Schuster, son of Stanley Schuster and Ruth Schuster, was born September 14, 1972 in Mt. Kisco, New York. He graduated from Wheaton College (IL) in August 1994 with a B.S. in Geology and a minor in Biology. From 1994 until 1997 Schuster’s work in the geological sciences included conducting, analyzing, and interpreting surface and ground water data, and coordinating and constructing a spring protection project that provided clean water for a small village in rural Haiti.

While Haiti he was asked to teach a geology course at a local high school. This and several subsequent experiences as a science educator prompted him to return to graduate school and in 1998 he received his Masters of Arts in Teaching and his Secondary Teacher Certificates in the Earth Sciences, Biology, and General Sciences from Cornell University. After completing his degree, Schuster, along with his wife, Nancy, taught in the New York State Public Schools and at private schools in Honolulu, Hawaii. In June 2002, he enrolled in the Ph.D. program in the College of Education at Penn State.