ELEMENTARY TEACHERS’ PERCEPTIONS OF SCIENCE INQUIRY
AND PROFESSIONAL DEVELOPMENT CHALLENGES AND
OPPORTUNITIES

A Dissertation in
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By
Kathleen M. Jones

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The dissertation of Kathleen M. Jones was reviewed and approved* by the following:

James F. Nolan
Hermanowicz Professor of Education
Dissertation Advisor
Chair of Committee

Carla Zembal-Saul
Kahn Associate Professor of Education

Denise Meister
Associate Professor of Education
Penn State Harrisburg

Edgar P. Yoder
Professor of Agricultural and Extension Education

Glendon Blume
Professor in Charge of Graduate Studies
Curriculum and Instruction

*Signatures are on file in the Graduate School.
ABSTRACT

Inquiry science, including a focus on evidence-based discourse, is essential to spark interest in science education in the early grades and maintain that interest throughout children’s schooling. The researcher was interested in two broad areas: inquiry science in the elementary classroom and the need/desire for professional development opportunities for elementary teachers related to science education, and specifically professional development focused on inquiry science.

A cross sectional survey design was prepared and distributed in May 2005 and usable responses were received from 228 elementary teachers from the south-central area of Pennsylvania which was a representative sample of socio-economical and geographical factors.

Areas of particular interest in the results section include:

1. The use of Science Kits which is popular, but may not have the desired impact since they are “adjusted” by teachers often removing the opportunity for evidence-based discourse by the students. This may be partly based on the lack of time dedicated to science instruction and, secondly, the teachers’ lack of comfort with the science topics. Another issue arising from science kits is the amount of preparation time required to utilize them.

2. Teachers demonstrated understanding of the high qualities of professional development but, when it came to science content professional development, they were more inclined to opt for short-term opportunities as opposed to long-term learning opportunities. Since elementary teachers are generalists
and most schools are not focusing on science, the lack of attention to a subject where they are least comfortable is understandable, but disappointing.

3. There is a great need for more training in evidence–based discourse so teachers can implement this needed skill and increase students’ understanding of science content so they are more able to compete in the international science and math measurements.

4. Professional development, especially in the science area, needs to be a long-term, grass-roots effort in all schools. We need to dedicate funding, and make time available for teachers to participate in long-term collaborative learning opportunities. Teachers want to observe each other and collaborate on lessons but, unless it becomes a priority of the school, it will not happen. Time must be dedicated throughout the day that allows small groups of teachers across the board to get together and share, learn, attempt new approaches, reflect and revise. Various forms of professional learning are available, and each school must choose the one that works for them.

5. The principal as the educational leader in the school needs to be more fully engaged with the learning process of the teachers and the students. The principal should not be viewed only as the evaluator of teachers, but as a collaborator of learning and teaching.

Suggestions for further research include longitudinal studies of the impact on students of long term professional development of the teachers that specifically targets science content, inquiry and evidence–based discourse.
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Chapter 1

INTRODUCTION

Introduction to the Problem

The National Science Education Standards (NRC, 1996) and the Pennsylvania Science and Technology Standards (PDE, 2001) both encouraged the process of inquiry and suggested this should begin as early as kindergarten. But do elementary teachers actually understand and utilize the elements of inquiry and engage their students in inquiry learning? The 2003 TIMMS (Trends in International Math and Science Study) test added inquiry for the first time as an important feature for assessing students’ knowledge of science (Martin, Mullis, Gonzalez & Chrostowski, 2004). Although there was some improvement in the test scores for U.S. students in the lower benchmarks—measuring science facts, the higher benchmarks which measure conceptual understanding and inquiry design showed a decrease for U.S. students indicating that inquiry and conceptual understandings remain outside the arena of elementary education (p. 60). Scientific inquiry must be introduced and reinforced starting in kindergarten in order to offer U.S. students the same opportunities to compete in international assessments.

Michaels, Shouse, and Schweingruber (2008) argued that “to the degree that we actually know science, we have knowledge and strategies with which to examine evidence systematically, interpret, and control our surroundings.... Without scientific knowledge, we are wholly dependent on others as ‘experts’. (Science) is a resource for becoming a critical and engaged citizen in a democracy” (p. 2).
The National Research Council (2000) offered a table of five essential elements of classroom inquiry realizing that there are varying degrees of inquiry design from a teacher-centered mode to a student-centered mode (Table 1). The five elements are as follows:

1. Learner engages in scientifically oriented questions
2. Learner gives priority to evidence in responding to questions
3. Learner formulates explanations from evidence
4. Learner connects explanations to scientific knowledge
5. Learner communicates and justifies explanations (p. 29)

The natural processes of science are to question, observe, gather data (evidence) and try to explain findings. Sharing results with others highlights the significance of the findings and extends knowledge. The opportunity to communicate and defend scientific findings, using “evidence” collected in the process of inquiring is a key factor in helping students to develop confidence in their scientific reasoning and understanding so they are scientifically literate by the time they leave the formal classroom.

The process of questioning and wondering is what has fueled our problem solving ability. The process is not necessarily a neat, orderly form that often comes pre-packaged in a box termed, “The Scientific Method”; rather it is the ability to question, gather evidence and learn from that experience. Many science “programs” currently occurring in elementary schools today are “pre-packaged” or textbook driven because teachers, potentially overwhelmed by the massive amounts of curriculum that “must” be covered,
Table 1. Essential Features of Classroom Inquiry and their Variations (NRC, 2000).

<table>
<thead>
<tr>
<th>Essential Feature</th>
<th>Variations</th>
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<tr>
<td>1. Learner engages in scientifically oriented questions</td>
<td>Learner poses a question</td>
</tr>
<tr>
<td>2. Learner gives priority to evidence in responding to questions</td>
<td>Learner determines what constitutes evidence and collects it</td>
</tr>
<tr>
<td>3. Learner formulate explanations from evidence</td>
<td>Learner formulates explanations after summarizing evidence</td>
</tr>
<tr>
<td>4. Learner connects explanations to scientific knowledge</td>
<td>Learner independently examines other resources and forms the links to explanations</td>
</tr>
<tr>
<td>5. Learner communicates and justifies explanations</td>
<td>Learner forms reasonable and logical argument to communicate explanations</td>
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**More**  
**Amount of Learner Self-Direction**  
**Less**  
**Amount of Direction from Teacher or Material**

Less  
More
do not have the time to dedicate to science instruction. This was one of the major criticisms that came out in the 1999 TIMSS report. Schmidt (2001), who serves as the National Research Coordinator for TIMMS, pointed out that typical eighth grade science textbooks cover approximately 65 topics versus 25 topics covered by other TIMMS countries (p. 158). In addition, Fulp (2002) countered that elementary teachers do not have the comfort level with science topics that they do with other topics such as reading and math. Elementary teachers are prepared as generalists and many do not have the depth of understanding in science.

The National Science Foundation suggested that inquiry is what allows societies to flourish. In the National Science Education Science Standards, the following explanation is offered to introduce the concept of inquiry, “In societies where inquiry has flourished, so has human progress. Athens of the fifth century B.C. comes to mind. The Agora – the marketplace where freedom-loving Greeks gathered to discuss the issues of the day – was a crucible of intellectual inquiry led by one of history’s most celebrated teachers, Socrates” (p. 5). Rowe (1973) pointed out that Socrates’ method of short responses from his students, leading them to his thoughts, may not be the best form of inquiry design, but does offer a starting place to understand what she terms “conceptual conflict” which prompts students to question and then dig deeper to gain a fuller understanding (pp. 342-343).

Rutherford and Ahlgren (1990) suggested that students often are thought to understand a concept, especially abstract concepts, because they have the ability to memorize information and offer it back to the teacher on a test. “As a result, teachers –
from kindergarten through college – sometimes overestimate the ability of their students to handle abstractions, and they take the students’ use of the right words as evidence of understanding” (pp. 186-187). The American Association for the Advancement of Science, in *Benchmarks* (1993) also pointed out that multiple choice questions which serves as the predominant means of testing “often inflate estimates of students’ understanding and disguise their misunderstandings” (p. 328). Inquiry investigations allow students to delve deeper into a subject and often misconceptions will come to light as students are encouraged to give priority to evidence. If identified through discussion, the misunderstandings can be changed into conceptual understanding of what is actually happening.

Dewey (1938) was a major proponent of experiential learning and even suggested that the scientific method “is the only authentic means at our command for getting at the significance of our everyday experiences of the world in which we live” (p. 111). In suggesting the scientific method, though, Dewey was referring to an organized way of viewing data and experiencing it so students could construct their own knowledge with the assistance of a guide (the teacher). He was not referencing the five to seven step “method” that is so often taught as THE scientific method.

More inquiry experiences should be incorporated into science instruction in elementary classrooms in order for students to grow and be able to co-construct their knowledge and understanding of the world around us. The opportunity to discuss their findings is a key aspect of inquiry that is often forgotten or put off due to time factors. A number of research reports focused on pre-service teachers’ experience with science
inquiry instruction and the need to re-vamp elementary science methods classes. A few studies with elementary teachers looked at professional development and one considered elementary teachers understanding of inquiry. Schibeci and Hickey (2004) looked at elementary teachers reluctance to attend science related professional development and found that if elementary teachers did not see the professional development as relevant, they would not attend and since the primary focus is on math and reading there was little interest in attending a science related topic. This feeling has begun to change in Pennsylvania as the science PSSA test became a reality. The Pennsylvania Science PSSA was pilot tested in spring 2007 and became part of the full testing in spring 2008, although it does not count toward Annual Yearly Progress (AYP).

Funk (2005) found important features of professional development included collaboration with colleagues and support from colleagues, but if the subject could not be integrated across the curriculum, it impacted reform efforts immensely. In a ten year study focusing on math and science reform, Banilower, Boyd, Paisley and Weiss (2006) found the menu-driven options that allow free choice were less effective in creating change than professional development that prescribed the workshops that teachers should attend. Akura (2004) also studying professional development found mentoring and self-reflection over a sustained period of time facilitated change in the elementary teachers. Banilower et al. (2006) found that continuous meetings (e.g., monthly meetings) throughout the school year helped to re-engage the teachers’ focus and commitment.

Domjan (2003), in a study of teachers’ perceptions of science inquiry, found that elementary teachers lacked an understanding of inquiry and suggested that long-term
professional development centering on inquiry teaching strategies would be highly recommended. This finding lies at the heart of the present study.

**Purpose of the Study**

The purpose of this study was to determine Pennsylvania elementary teachers’ perceptions and understanding of inquiry as defined by the National Science Education Standards (NSES) and advocated by the Pennsylvania Science and Technology Standards. In addition, the study determined approaches to professional development that will “fit” the elementary teachers’ schedules while achieving the goal of introducing and implementing more inquiry within elementary classrooms. A number of studies examined teachers’ understanding of inquiry or professional development related to elementary science, but few considered both aspects.

The present study is designed to address four primary questions, one of which has three sub-questions as outlined below:

1. Do Pennsylvania elementary teachers define science inquiry in a similar way as it is defined in the National Science Education Standards?
   a. How familiar are Pennsylvania elementary teachers with the Pennsylvania and National Science Standards, especially in relation to inquiry?
   b. Do Pennsylvania elementary teachers recognize the definitions of science inquiry used in the National Science Education Standards (NSES) and Pennsylvania Science and Technology Standards (PSTS) when the definitions are stated literally?
c. Do Pennsylvania elementary teachers recognize the definitions of inquiry used in the National Science Education Standards (NSES) and Pennsylvania Science and Technology Standards (PSTS) when the definitions are stated in context?

2. What is the relationship between self-reported familiarity with NSES, recognizing NSES definitions of science inquiry literally and recognizing NSES definitions of science inquiry in context?

3. To what degree do Pennsylvania elementary teachers agree with accepted principles of effective professional development?

4. To what degree are Pennsylvania elementary teachers willing to participate in professional development activities that match accepted principles of effective professional development when the professional development is focused on science inquiry?

Significance of Study and Possible Results

The 2003 TIMMS results showed that U.S. students improved in the lower half of the proficiency distribution, but “had decreased performance at the advanced and high international benchmarks” (Martin, et al., 2004, pp. 59-60). Could this decrease be a reflection of the addition of inquiry in the test?

Scientific concepts surround us, and unless we develop scientifically literate students, the future decision makers will not understand the potential impact their decisions may have on our environment or the potential advancements in medicine or
other areas that might be lost due to a lack of funding. Interest in science is naturally occurring in young children, yet many are “turned off” to science by the middle and high school years. Dedicated elementary teachers and parents must harness this natural curiosity. But how do we “add” more to an already overcrowded curriculum and how do we better prepare teachers to be effective science teachers?

One of the most difficult parts of inquiry-based learning is fulfilling the opportunity to have students communicate and justify their results – tying their results to scientific evidence. This is scientific discourse and I believe this is the most neglected part of inquiry learning.

I believe that science inquiry was not, and is not, well defined in Pennsylvania’s elementary classrooms. My perception is that science is limited to a few “hands-on” activities designed to get the students “excited” about science, but not taking it to the next level in having students truly study the evidence, formulate explanations based on the evidence, connect to other science knowledge and communicate those results to others (as defined by NSES). A major emphasis in Pennsylvania elementary classrooms is on math and reading success as measured by the Pennsylvania School System Assessment (PSSA) standardized testing that is used to fulfill the requirements of the No Child Left Behind (2001) legislation. With the pressure for all children to reach “proficient” level by 2014, often science lessons are skipped, relegated to the end of the day, or quickly reviewed so more time can be spent on math and reading instruction. Although the PSSA Science Assessment was pilot tested in spring 2007 and came out as a full-fledged test in
2008, to fulfill the mandates of NCLB that all states assess science by 2007, but many districts in Pennsylvania are still ignoring science education.

Teachers are reluctant to see science as a means of teaching math and reading content. According to Fulp (2002), a majority of “elementary school teachers do not feel equally qualified to teach all academic subjects, with preparedness to teach science paling in comparison to mathematics, language arts and social studies” (p. 5). She went on to report that 77 percent are very comfortable with reading and language arts instruction, 66 percent are very comfortable with mathematics and 52 percent feel the same about social studies; only 3 percent feel very comfortable with science. Furthermore, of those who feel well qualified to teach science, most felt more comfortable with life science and earth science versus the physical sciences. When compared to the elementary teachers’ college course work, correlations were drawn which attested to the levels identified (p. 5). Elementary teachers reported a high degree of pedagogical preparedness, especially in relation to working with students in “hands-on” activities and cooperative grouping (p. 19). But this concept of hands-on work must be clarified because Weiss, Banilower, McMahon and Smith (2001) reported that elementary teachers feel less prepared than middle school and high school teachers to lead discussion and delve deeper into the scientific concepts, while helping students develop a conceptual understanding. They are also less inclined to help students make the connections between science and other course work and even within science itself, much less feeling comfortable enough to lead investigations or manage students working in a “hands-on” environment or with projects (p. 29). The term “hands-on activities” is used quite a bit, but hands-on does not
necessarily equate with inquiry based learning. On the other hand, NSES also pointed out that employing reading strategies is not inconsistent with inquiry based instruction (NRC, 1996, p. 23).

If teachers were given the opportunity and would be willing to participate in high quality, professional development opportunities that offered experience in science inquiry, they may be more inclined to incorporate science inquiry in their classroom, and possibly connect it to the other subjects of reading and math. In addition, if teachers would be willing to work together in a collaborative sharing environment after hours or during school hours (if time could be carved out for such meetings), they might find the experience enriching and invigorating, adding a new dimension to their teaching styles as they share experiences and try new approaches. The Science and Engineering Indicators 2006 reported that teachers who had numerous hours (60-80 hours) of professional development training in higher order thinking skills related to math and science resulted in higher test scores of students (National Science Foundation, 2006).

Boyd, Banilower, Pasley and Weiss (2003) reported on the NSF-funded professional development opportunities employed by some districts entitled “Local Systematic Change through Teacher Enhancement” (LSC). They found that LSCs were trying to balance the professional development with both accurate and up-to-date content and pedagogy, without “sacrificing” the content. A key component was also the reflection piece by teachers about the new material and implementation. Following summer workshops that lasted typically one week or longer, the year-long follow-up mandated by the NSF grant, included meeting with colleagues to discuss implementation
strategies and to further develop content knowledge. This approach was met with mixed reviews since although the teachers were “mandated” to attend, it was not always possible and so different groups of people met for the meetings. Boyd et al. (2003) also found that, “once teachers believed they ‘got it’ (e.g., inquiry), they saw little need to participate further” (p. 48).

Fulp (2002) reported that collaboration with peers is the second most common form of professional development with approximately 33 percent of responding elementary teachers observing each other and 27 percent meeting regularly to discuss science teaching (p. 9). But Weiss et al. (2001) pointed out that elementary teachers realize the need for professional development related to science, but the lack of time is a major drawback. In addition, if given options, elementary teachers are less likely to choose science as their option. Weiss et al. (2001) discovered that over two-thirds of the teachers who participated in professional development indicated that it did not impact his/her teaching (p. 45). This potentially could be due to the short-term professional development opportunities offered teachers through one-day workshops, which was the most common form of professional development for the majority reporting (Fulp, 2002) as opposed to a longer-term commitment of professional development. Darling-Hammond, Wei, Andree, Richardson and Orphanos (2009) reported that little has changed about professional development stating, “(P)rofessional learning in its current state is poorly conceived and deeply flawed. Teachers lack time and opportunities to view each other’s classrooms, learn from mentors, and work collaboratively. The support and training they receive are episodic, myopic, and often meaningless” (p. 2).
Boyd et al. (2003) suggested a minimum of 80 hours of professional development is needed to facilitate change in science instruction. A longer-term commitment to professional development in science will mean more resource expenditure for both the school/district and the teachers personally. Ferrell (2002) suggested that longer-term professional development, as long as it is focused, will impact teachers’ strategies in delivering content. She found that the two areas of weakness in long-term professional development were in the areas of establishing and maintaining the learning community, and continual assessment to improve the professional development offerings. Ferrell strongly recommended that a pre-assessment of the teachers’ knowledge, skills and perceptions be conducted to help focus the long-term professional development. The Science and Engineering Indicators 2006 found that teachers’ effectiveness was strongly enhanced when the professional development opportunities encouraged collaboration of teachers from the same building or department and included, “active learning opportunities such as reviewing student work or obtaining feedback on teaching; and coherence such as linking to other activities or building on teachers’ previous knowledge” (National Science Foundation, 2006, p. 36).

Definitions

The following are brief definitions, some of which will be elaborated on in Chapter 2.

*Science inquiry* – The term scientific inquiry is hotly debated within the science community, but for purposes of this study, I am using the definition from the National
Research Council’s National Science Education Standards: “Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to 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” (NRC, 1996, p. 23).

Scientific inquiry is further defined by the National Research Council (1996) as a (M)ultifaceted activity that involves making observations; posing questions; examining books and other resources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations. (p. 23)

The major emphasis in inquiry learning is on the use of evidence to “prove or disprove” the proposed hypothesis, but of equal importance are the ideas that students should learn to pose testable questions, write explanations of the evidence, tie it into previous scientific knowledge and ultimately share the results and justify the explanation, not just to the teacher, but to the community of learners (NRC, 2000, p. 29).

The Pennsylvania Science and Technology Standards defined inquiry as “an intellectual process of logic that includes verification of answers to questions about and explanations for natural objects, events and phenomena” (2001, p. 4).

Hands-on instruction – Often considered the first component of inquiry, hands-on activities are those activities that actively engage a student in the processes of science. Often though, that is where instruction ends and the second component of “minds-on” learning is not fulfilled. Students enjoy “hands-on” activities, but often are not
challenged to make the connections with other scientific knowledge and understanding and to defend their understandings. It is important to note that not all “hands-on” instruction is inquiry based and inquiry instruction does not necessarily have to include “hands-on” activities.

**Scientific discourse** – Another essential feature of inquiry, allows learners to publically share their thoughts and explanations, basing it on evidence, but also reviewing alternative explanations that are considered within the “norms” of science and logic. In addition, it offers students the opportunity to question other students’ arguments, in a respectful way, by reviewing scientific evidence based on observations or new evidence and not just a “feeling” (Duschl, Schweingruber & Shouse, 2007).

**Processes of science** – The processes of science are considered to be the organized fashion in which scientists explore how the world works and include the ability to question, gather evidence, and try to explain that evidence connecting it to prior scientific knowledge. “To participate fully in the scientific practices in the classroom, students need to develop a shared understanding of the norms of participation in science. This includes habits of mind, such as adopting a critical stance, a willingness to ask questions and seek help, and developing a sense of appropriate trust and skepticism” (Duschl et al., 2007, p. 40).

**Scientific literacy** -- Scientific literacy is the concept that everyone is a consumer of science. Science surrounds us daily and everyone, even the most reluctant student of science, cannot get away from it. Therefore, it is necessary that every consumer have a
working knowledge of science so he or she can make informed decisions. According to
the American Association for the Advancement of Science (AAAS) (1993),

(S)cience literacy requires understandings and habits of mind that enable
citizens to grasp what those enterprises are up to, to make sense of how
the natural and designed worlds work, and to think critically and
independently, to recognize and weigh alternative explanations of events
and design trade-offs, and to deal sensibly with problems that involve
evidence, numbers, patterns, logical arguments, and uncertainties. (p. XI)

Scientific literacy is NOT a list of vocabulary words and terms that students need to
memorize; but scientific literacy is a goal that all students should strive to achieve.

Paul Hurd, a biologist and educator, is credited with coining the term, scientific
literacy, in 1958 defining it, “in the context of the current society, thus recognizing the
interactive relationship between science as a discipline and the society in which it is
practiced” (Krueger & Sutton, 2001, p. v).

**Pedagogical content knowledge** (PCK) in science– Kelly (2000) defined it as,
“…a collective, working knowledge of science that enables the teacher to re-cast science
in a way that effectively communicates understanding to the learner whether the
negotiated experiences involve discussion, inquiry-based investigations, or reflective
exploration and explanation” (p. 756). It entails knowing how to put information into age
appropriate terms and experiences for the students. PCK also means helping learners to
connect this learning to other instruction. PCK becomes important when trying to make
science make sense for students.

**Professional development** – Professional development is defined by the National
Staff Development Council (NSDC) as the “term that educators use to describe the
continuing education of teachers, administrators, and other school employees”
In addition to the more traditional forms of conferences, in-service training, workshops and graduate coursework, the NSDC also offers additional examples of what might constitute staff development including: 1. Teachers planning lessons together; 2. Studying a subject together; 3. Observing someone else’s teaching; 4. Being coached by another teacher; 5. Visiting model schools; 6. Writing curriculum; and 7. Maintaining a journal about teaching practices. Darling-Hammond et al. (2009) further described the view of an effective professional development community as one where, “Teachers meet on a regular schedule in learning teams organized by grade-level or content-area assignments and share responsibility for their students’ success” (p. 3).
Chapter 2
LITERATURE REVIEW

The literature review begins with more in-depth definitions of some concepts and continues by highlighting the proposed use of inquiry in science classrooms at different time periods and highlights some of the work of Joseph Schwab and John Dewey. It continues on to outline the work of the American Association for the Advancement of Science (AAAS) and the publication of the National Science Education Standards (NSES) in 1996. In addition it serves to highlight the similarities and differences of inquiry from the scientist’s perspective versus the student studying in the classroom. TIMSS reports are addressed, in addition to other reports including the Science and Engineering Indicators 2006 report and From Kindergarten through Third Grade: Children’s Beginning School Experiences 2004. In addition four books of particular note are: the Handbook of Research on Science Education (2007); Taking Science to School (2007); Elementary Science Teacher Education (2006); and Ready, Set, Science (2008).

This section concludes with a review of the literature regarding professional development opportunities for teachers who teach science. There have been many recommendations that teachers should receive both pedagogical and content instruction during professional development especially in the science area, but this rarely occurs. Teachers often are given materials or “kits” but without the background in using them, these resources become one more item that is shelved. The “Science, It’s Elementary”
project in Pennsylvania elementary schools tries to address these issues and is also
discussed.

**Science Inquiry, Scientific Literacy, Nature of Science,**
**and Scientific Discourse**

Science inquiry is not a new concept, although the publication of the *National Science Education Standards* (NSES) in 1996 brought it to the forefront. Scientific inquiry has been very much alive in various parts of the curriculum, some say, even
dating back to Socrates as he guided his students to think (Rowe, 1973; National Science
Foundation, p. 5). Joseph Priestley suggested in 1790, “Children should be trained to
perform experiments and deal with the theory and practice of enquiry at an early age”
(Priestley, 1997). The vocational agricultural curriculum (now called agricultural
education), since its inception in 1917 with the passage of the Smith Hughes Act, has
based its philosophy of teaching on the concept of inquiry, and even the National FFA
motto is based on this concept: “Learning to Do, Doing to Learn, Earning to Live, Living
to Serve.” John Dewey was a major proponent of experiential learning and Joseph
Schwab credits Dewey with offering him the philosophical basis of inquiry learning
(Westbury & Osborne, 2003). So what exactly is scientific inquiry and how does it differ
from scientific literacy and the nature of science?

As Roberts (2007) pointed out, the term science literacy or scientific literacy is
still hotly debated with the science community. For purposes of this study, I am using
what Roberts termed “Vision I” and defined as the “looking inward at the canon of
orthodox natural science, that is, the products and processes of science itself” (p. 730).
Science literacy differs from science inquiry in that scientific inquiry is one means of becoming more scientifically literate. Not all students “enjoy” inquiry roles, yet it is essential that all students become literate consumers of the science world. As they grow into adulthood, this scientific literacy will play an essential role as they make informed decisions ranging from their own personal welfare to supporting or not supporting national and international movements potentially ranging from continuing space exploration to nuclear or thermonuclear power. According to AAAS (1993) if people have a working knowledge of how scientists go about doing their research, they will be more likely to carefully consider findings as opposed to either accepting them unconditionally or rejecting the findings due to a lack of understanding.

The NRC (1996) summed up scientific literacy as the ability to critically read and assess articles published in the newspaper and carry on a well-reasoned conversation about the findings. In addition, it entails the ability to explain natural phenomena and to investigate questions about everyday experience in a logical format.

The term “Nature of Science” (NOS) is also hotly debated within the science community and, as Lederman (2007) pointed out, has been for at least 100 years. He also said that scientific inquiry and the nature of science are “intimately related.” Lederman further pointed out that, “(T)here is much evidence that NOS is best taught within a context of scientific inquiry or activities that are reasonable facsimiles of inquiry. That is, inquiry experiences provide students with foundational experiences upon which to reflect about aspects of NOS” (p. 835). The nature of science is summed up in the concept that science is a human endeavor in an attempt to explain how the world works.
Human curiosity is the driving force that encourages us to question and wonder; scientific endeavors are the logical process that we use to attempt to explain the workings of the universe. Rutherford and Ahlgren (1990) opened their book, *Science for All Americans*, by explaining:

> Over the course of human history, people have developed many interconnected and validated ideas about the physical, biological, psychological, and social worlds. Those ideas have enabled successive generations to achieve an increasingly comprehensive and reliable understanding of the human species and its environment. The means used to develop these ideas are particular ways of observing, thinking, experimenting, and validating. These ways represent a fundamental aspect of the nature of science and reflect how science tends to differ from other modes of knowing. (p. 3)

Scientists tend to go about their work in a logical format, using questions that pique their curiosity as the driving force to their discoveries. “More imagination and inventiveness are involved in scientific inquiry than many people realize, yet sooner or later strict logic and empirical evidence must have their day” (AAAS, 1993, p. 9). Yet the primary impetus of the nature of science is to find out how and why the world works in the manner it does.

Lederman (2007), in further trying to distinguish the nature of science, explained that NOS “typically refers to the epistemology of science, science as a way of knowing, or the values and beliefs inherent to scientific knowledge, and its development” (p. 833). He offered the following six characteristics to further define it (pp. 833-834):

1. Students should understand the crucial distinction between observation and inference.
2. Closely related to the distinction between observations and inferences is the distinction between scientific laws and theories.

3. Even though scientific knowledge, at least partially, is based on and/or derived from observations of the natural world, it nevertheless involves human imagination and creativity.

4. Scientific knowledge is subjective and/or theory laden.

5. Science as a human enterprise is practiced in the context of a larger culture, and its practitioners (scientists) are the product of that culture.

6. It follows that the previous discussions that scientific knowledge is never absolute or certain.

Finally, in relation to scientific discourse, it is important that it be defined since it is an essential part of students’ learning. Discourse was broadly defined by Kelly (2007) as “language in use, or a stretch of language larger than a sentence or a clause” (p. 444), but he was quick to point out that “the study of discourse processes in science education should properly include a definition of discourse as using language in social contexts, and connected to real practices” (p. 444). For students to fully participate in inquiry and the scientific processes, and have an understanding of the nature of science, they must be able to fully engage in discussion and writings that clearly define what they initially thought, the processes they carried out, changes in their thinking and their findings based on evidence. They must also be willing to engage in a dialogue with others and not only challenge their own findings, but be willing to challenge the findings of others based on alternative explanations that would be found within the accepted realm of the science
community. “Science advances in large part through interactions among members of research communities as they test new ideas, solicit and provide feedback, articulate and evaluate emerging explanations, develop shared representation and models, and reach consensus” (Duschl et al., 2007, p. 40). If we do not offer our students this opportunity, we are limiting their abilities to more fully participate in future scientific work.

**Early Work on Inquiry: Joseph Schwab and Enquiry**

Joseph Schwab would warn that this might be a simplistic definition of the nature of science saying instead that it depends on whom you ask. In his essay, *Scientific Knowledge and Liberal Education* originally published in 1949, Schwab (1978a) explained:

Diversity of view concerning the nature of science is then an inescapable fact. And this inescapable fact implies one immediate caveat to the architects of liberal programs in the natural sciences. The caveat is that no one doctrine concerning the nature of science can be exclusively employed as a principle of organization and interpretation or taught by the architect in the program he develops. To employ only one doctrine as a principle will give rise to a biased view of the nature of science and to teach a single doctrine could be to the student only misleading or confusing or both, because no single doctrine is more than a partial statement – partial in the sense of incomplete and partial in the sense of being based upon a set of epistemic or metaphysical presuppositions. (p. 72)

Schwab’s interest in “enquiry” dates back to his work in the 1940’s and he coined the spelling in 1958 because some educational psychologists interested in how children set about solving problems termed this approach inquiry. So as not to confuse the two types, Schwab adopted the spelling of inquiry with an “e” (Westbury & Wilkof, 1978, footnote 3). His initial work was involved in designing a course of study for liberal arts
education and he wanted to include the various disciplines of science. Realizing the vastness and the contradictory methods that may apply across the disciplines, he was perplexed by the enormity of the situation. He felt strongly that science should not be a list of terms to be memorized, but rather that students should experience science and then learn the vocabulary as deemed appropriate. He also did not feel it appropriate to only offer one view or method of inquiry (Schwab, 1978a). Schwab was determined that science should be an investigation and that students in the process of learning science should be actively involved in discussion of evidence as it comes to light. Through this active engagement he felt that students would not experience

parrot-knowledge, for the student knows each conclusion in terms of the evidence which established it, the competitions with alternative formulations through which it has won its way and the revisions which it has undergone in the continuing process of enquiry. Knowledge about science thus gained could not be parrot-knowledge, for there will have been no speeches or prefaces about science to copy. Instead, the knowledge will be operational – gained, practiced, and perfected upon varied examples of scientific enquiry. (p. 97)

Schwab’s concepts might have been the basis of the term, “hands-on, minds-on” science that is one of the popular terms used to describe today’s science inquiry practices, but prior to Schwab’s work, another professor, Dr. Joseph Kranskopf, founder of Delaware Valley College in Doylestown, PA stated in 1896 that students learn using both minds and hands (Diamond, personal interview, October 23, 2005).

In a later essay, originally published in 1956, entitled Science and Civil Discourses: The Uses of Diversity, Schwab (1978b) elaborated on his thoughts of the importance of enquiry as a process to lead the student to the “construction of knowledge.”
If, on the other hand, the curriculum illustrates with care the participation of principles in the construction of knowledge and exhibits the growth of knowledge which occurs via the increasing adequacy of successive principles imposed in enquiry, the student can see the ground for change and revision. He sees that authority consists not in possession of information but in possession of competence in enquiry; change in what authority says no longer appears as a sign of confusion or mere change in fashion but as a sign of the progress of enquiry. (pp. 134-135)

John Dewey was a major influence on Schwab in this thought process. He proposed at a 1909 meeting of the American Association for the Advancement of Science that science should not be a collection of facts and terms to be memorized, but rather a state of mind, and that, “there is a process or method to learn” (NRC, 2000).

Scientific Inquiry and Its Role in School Science

Dewey through his laboratory schools and Schwab through his influence on science courses taught at the college level tried to have a major impact on the teaching and learning of science, but the impact has not been universal. The launching of Sputnik in 1957 caused uproar and a call for better science education in American schools. The National Science Foundation (2006) saw a major increase in funding from $130,000 in 1955 to an impressive $40,000,000 in 1959 and $60,000,000 in 1964. In addition, a number of inquiry-based programs were sponsored and produced with the support of NSF grants (Carin, Bass & Constant, 2005; Atkin & Black, 2007). Schwab was recognized for his approach to liberal arts education and seen as a spokesperson for the “importance of disciplined-based teaching of science in the schools” (Westbury & Wilkof, 1978, p. 24).

According to Westbury and Wilkof (1978), Schwab did “identify himself with the ‘structure of the disciplines’ movement, although he well recognized that there was a
fundamental difference between his conceptions and those of the more conventional disciplinary scholars who also figured prominently. …it was his hope that something might be achieved that could be recognized as more ‘educative’ than what had been done before” (p. 25). Schwab was credited with the publication of the original BSCS1 Teachers’ Handbook and three additional BSCS biology works. Later research findings of Schwab’s own students suggested that the BSCS biology material was not being used in the way it was intended by both teachers’ institutions and the teachers in the field (Westbury & Wilkof, 1978).

Rowe, (1973) in Teaching Science as Continuous Inquiry, recognized that it was possible that the people using the materials would not necessarily utilize it in the same manner as intended by the authors or editors. The same could be said of the various labs and kits that have been produced over the years. Although wonderful in their inception, if not properly used by the teacher, the student, the ultimate consumer of this science instruction, is left with a series of tasks that have supposedly moved them along in their understanding of the content, but the student may not have a clear understanding of the content. Rowe recommended following a task analysis procedure to ensure that this does not occur with the final step being, how will the students’ learning be evaluated? Unfortunately, even today, many teachers still rely heavily on paper and pencil assessments, either produced by the textbook company or teacher created.

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1The BSCS program stands for Biological Science Curriculum Study. The BSCS website indicates that it is celebrating 45 years as an “Innovative, inquiry-based science education” program. “BSCS writes science curriculum materials, provides professional development programs, and conducts research and evaluation for K-16 science” (http://www.bscs.org).
In the 2000 National Survey of Science and Mathematics Education, Weiss et al. (2001) reported that 49 percent of K-4 teachers “Give predominantly short-answer tests (e.g., multiple choice, true/false, fill in the blank) compared to 81 percent of teachers in grades 5–8” (p. 77). Weiss et al. also found five common strategies that elementary teachers use to determine students progress:

- Asking students questions during large group discussions
- Using assessments embedded in class activities to see if students are ‘getting it’
- Observing students and asking questions as they work individually
- Observing students and asking questions as they work in small groups
- Reviewing student homework (p. 77).

The American Association for the Advancement of Science, in *Benchmarks* (1993) pointed out that, for years, multiple choice testing was the primary form of assessing students’ knowledge, but have now found that these tests often “inflate estimates of students’ understanding and disguise their misunderstandings” (p. 328), yet we know that teachers continue to rely on these forms of evaluation and standardized tests are using this format also. Until we break free of this artificial assessment form, inquiry will not achieve its full potential and we will leave students behind.

The concept of inquiry as a “hands-on, minds-on” teaching method has evolved from the days of Schwab’s concepts, at least on paper, but the way that it is being implemented in classrooms varies according to the teacher. The National Commission on Science and Mathematics Teaching for the 21st Century (2000) recommended that both
science content and pedagogy are essential and should be included in professional
development opportunities for elementary teachers. Teachers who are trained and feel a
comfort level with inquiry science are witnessing the results of their efforts, namely
students who are engaged in the process of “constructing” their scientific knowledge.
Klein (1998) pointed out that many teachers do believe in the constructivist view of
learning that allows students to construct their knowledge together using inquiry as the
primary means as opposed to the heavy reliance on textbooks and lectures. Klein
criticized the prescribed textbook or traditional lab reports because they only require
students to report methods, results and conclusions. He warned that students are only
making causal inferences and may correctly identify issues without having to justify the
response. He further emphasized that by using an inquiry approach, students are forced
into defending their results with the use of evidence and he also encourages teachers to
take it to the next level by offering “hypothetical beliefs based on misleading evidence, or
in the course of experimental inquiries, they could ask students to state alternatives to
their hypotheses and possible evidence that would support those alternatives”
(Discussion, ¶ 8).

Anderson (2007) specified that inquiry learning is very similar to the
constructivist approach, but that constructivism is viewed by some in a negative light and
therefore was not included in the NSES. “As with inquiry, the constructivist label can be
applied to the nature of science, learning and teaching, but it has even greater potential
for misunderstanding…. Thus inquiry has more potential for being a useful word that can
be applied in these three contexts without undue miscommunication” (p. 809).
But not all teachers have been trained in viewing inquiry as a viable method of instruction and other teachers see it as a “waste of time” or something that will consume more time than they have. These teachers hold firm to the belief that textbook knowledge is just as valuable if not more so because they are able to “cover” more of the prescribed curriculum. Duschl et al. (2007) in Taking Science to School: Learning and Teaching Science in Grades K-8 criticized U.S. textbooks, explaining, “U.S. textbooks fail to guide teachers in how to build on students’ understanding, to contextualize science in meaningful problems, or to treat complex ideas other than superficially” (p. 253). Weiss et al. (2001) reported that, “On the average, science lessons appear to be relatively similar in instructional arrangements in the various grade levels, with roughly 33-37 percent of the class time spent on whole class lecture/discussion; 22-30 percent of the time on hands-on activities; and 14-18 percent of the time with students working individually reading textbooks and completing worksheets. The remaining time, approximately 10 percent of the class time, was spent on non-instructional activities, including daily routines and interruptions” (p. 69).

The Standards of Science as Inquiry and Teaching Science as Inquiry – What are the Implications for Teaching and Learning?

The National Science Education Standards (NRC, 1996) identified two concepts for the “science as inquiry” standards for grades K-12: (1) Abilities necessary to do scientific inquiry and (2) Understanding about scientific inquiry. In further defining this, the NSES stipulated, “Inquiry is a step beyond ‘science as a process,’ in which students learn skills, such as observations, inference, and experimentation. The new vision
includes the ‘practices of science’ and requires that students combine processes and scientific knowledge as they use scientific reasoning and critical thinking to develop their understanding of science” (p. 105).

Teachers are challenged to teach not just activities that engage students (typically considered “hands-on” activities), but rather to offer authentic activities, projects and experiments that will challenge students’ thinking and current conceptions. Students develop their conceptions of science as they experience it, but it must be offered in a meaningful manner that will extend their current knowledge. Students, like scientists, use science to try and understand the world around them, but they must be offered opportunities to explain and justify reasoning of their understanding and conceptions to their peers and others based on evidence and their analysis of the evidence.

Teachers, especially at the elementary level, must be allowed the time to engage students in science inquiry. Currently a major emphasis in elementary education is on reading and math skills and little if any time is dedicated to science learning. Weiss et al. (2001) found in a national survey that self-contained K-3 classes, on a daily basis, spent an average of 115 minutes on reading, 52 minutes with mathematics, and only 23 and 21 minutes on science and social studies, respectively. For grades 4–6, it did not change drastically with reading and math receiving the primary attention at 96 and 60 minutes, respectively, and only 31–33 minutes being dedicated to science and social studies, respectively (Weiss et al., 2001).

The emphasis placed on science instruction varies from building to building and district to district, but with the current emphasis on reading and math skills as measured
by standardized testing, this trend toward less science time is sure to continue.

Integration of the subjects, science as a primary and motivating force is a potential solution, but only if teachers feel a comfort level with engaging students in inquiry activities where there is not necessarily a right answer. Shymansky (1997) pointed out that because the curriculum is so packed, elementary teachers will often teach using primarily themes that cut across at least two disciplines. Therefore, if the science content does not fit into the theme, it is given little attention. Wieseman and Moscovici (2006), in working with pre-service elementary teachers, found a standards infused curriculum has potential as long as the pre-service teachers were willing to dedicate the time necessary to implement the idea that the elementary students had to be actively engaged in the inquiry process, moving towards full inquiry if possible and not fall into the trap of a “linear, text-based, prescribed curricula” (p. 192). The pre-service teachers also differentiate between standards infused and “activitymania,” a term coined by Moscovici and Nelson (1998), where a lot of activities considered to be interesting and fun occur with a common thread, but little consideration is given to higher order thinking skills and scaffolding of information; the end result being a lot of “hands-on” activities that the elementary students enjoy, but are not able to tie into the specific learning theme.

In the standards infused approach, a major limiting factor that was recognized by all parties was the amount of planning time necessary to pull it together. Trying to scaffold the questions and learning activities and maintaining the interdisciplinary inquiry proved to be a major challenge on time and content knowledge. The pre-service teachers worked hard to design higher-order thinking activities that would engage the students and
move them forward in the guided interdisciplinary inquiry unit, but they also
acknowledged that although it took a lot of time to plan, read and understand the
resources, it was worth it. One pre-service teacher reported, “The more prepared you are,
the more you are able to handle children shooting questions at you” (Wieseman &

Metz (1997) pointed out her earlier work in 1995 that she proposed that young
children, due to cognitive development, could not process science inquiry, and she
recommended that their science instruction should be limited to observing, categorizing
and ordering things. She also felt that children could only handle concrete ideas since
they are concrete thinkers. And her third assumption was that children will not
understand experimental controls and therefore suggested that all science investigations
should be postponed until they are old enough to draw appropriate inferences and
communicate the results.

But Metz (1997) concluded, “these three assumptions are ill-founded and that this
approach to children’s science education significantly underestimates the potential of
children’s scientific reasoning abilities” (Introduction, ¶2–4), and suggested that it is
possible that effective instruction could change this in the section entitled “Confounding
Weak Knowledge with Developmentally Based Cognitive Deficiencies,” (¶ 11). Egan
(2005) supported this finding, proposing that we may be limiting younger students when
we only offer them the “concrete” examples. Critical of Spencer’s and Piaget’s works
which form the basis of a lot of instruction, Egan proposed that we review the basis of
these theories that young students can only move from the concrete to the abstract.
Duschl et al. (2007) also supported reviewing these assumptions and reported, “variability in scientific reasoning within any age group is large, sometimes broader than the differences that separate contiguous age bands….what children are capable of doing without instruction may lag considerably behind what they are capable of doing with effective instruction” (pp. 42-43). In explaining why the discrepancy may prevail, they explained, “Often, studies in developmental psychology do not have an instructional component and therefore may be more informative about starting points than about children’s potential for developing scientific proficiency under effective instructional conditions” (p. 43).

How School Science Differs from Scientists’ Science – Implications for Student Learning

School science is often considered contrived experiences designed to “move” students from step A to B. Time also becomes a major limitation as artificial time constraints are imposed. Scientists, as they research, are not limited by these artificial constraints in the same manner. They may explore a topic for as long as they wish (or as long as the “grant” money exists). Often in school science, a “scientific method” of investigation is used as the process for conducting all experimentations, rather than as a “fluid” guide. Scientists view following these step-by-step procedures contrived as they themselves often go back and forth among the “steps.” Teachers must be more willing to break out of the step-by-step procedure and view inquiry in a more dynamic mode.

Carin et al. (2005), in explaining the difference between scientists’ mode of inquiry and school inquiry, identified the developmental differences between children
and adults and offered the concept that school science can be used as a model to show students how scientists go about their investigations. Michaels et al. (2008) pointed out “students can’t behave exactly like scientists. They don’t yet know enough and haven’t had enough experience with the practices of science. But students who understand science as a process of building theories from evidence develop many of the skills and practices that scientists demonstrate” (p. 6). Carin et al. explained, “The key ingredient in accommodating scientific inquiry to the level of children is the teacher, who plans, prepares, presents, hints, prompts, questions, informs, guides, directs, tells and explains – all in the context of children’s hands-on engagement with the objects and organisms of the real world” (p. 24).

Research indicates that direct instruction may be effective for conveying facts, but it does not necessarily translate into “higher order cognitive skills such as reasoning and problem solving” (Intellectually situating the sociocultural revolution in instructional research, ¶ 3). This is where inquiry teaching comes into play (Palincsar, 1998).

Offering authentic assessments and real-life projects, where appropriate, will allow students to experience science in a “real” setting. While this is not always possible due to time constraints, opportunities do arise for authentic experiences as students raise questions about the physical and natural worlds. If teachers were “tuned” in to their students, these opportunities offer a chance for students to move beyond traditional “textbook” learning into the realm of learning to work in the real world. Student directed inquiry or full inquiry, the ultimate goal, offers the best opportunity for students to gain from this enriching experience. Teachers must be open to this possibility and students
must be willing and confident enough to take the “risk” of moving beyond the textbook, and moving beyond the science kit type experiences. In addition, administrators and parents must be willing to support this initiative.

Carlsen (2007) pointed out that the “science classroom sits on the border between competing cultures, such as the scientific community, which values open inquiry and disagreement, and the formal school community, which generally prefers quiet obedience” (p. 60). Breaking out of this mode and allowing teachers and students alike to actually engage in inquiry may be the greatest challenge to overcome.

Akerson and McDuffie (2006) proposed that teachers should become researchers themselves and use action research techniques to drive their decision making process in what they teach. “Even elementary teachers who are confident in their science backgrounds and teaching approaches could benefit from conducting an inquiry project, and could improve their teaching practice with systematic study” (p. 259). Teachers should also let the students and their parents know that they are actively researching, modeling the inquiry approach in a social science setting.

Porlan and Martin del Pozo (2004) found in a multifactorial analysis of the Inventory of Scientific and Pedagogical Beliefs (ISPB) three models of teaching science for in-service and pre-service teachers that closely resemble earlier studies:

1. Traditional model. It represents an ascientific conception of the teaching learning process whereby it is sufficient that the teacher knows the content and possesses certain human qualities. A package of finished content is directly transmitted to the pupils (p. 52).
2. *Technical model*. This conceptualizes teaching from a viewpoint of an instrumental rationality. If the teachers apply the prescribed techniques in their classroom, learning is guaranteed. The objectives and a closed sequence of activities are programmed in detail to form the framework for the structure of classroom practice. Evaluation is on the level attained relative to the declared objectives (pp. 52-54).

3. *Alternative model*. This tendency reflects the complex character of teaching and the importance of pupil participation and the teacher’s role as investigator…. Nevertheless, this was a minority tendency in our sample…. We feel that these results may be understood in light of the sparseness of the implementation of models that are real alternatives to the traditional way of teaching (p. 54).

This third model, the alternative model, is the one that comes closest to the inquiry approach proposed by the NSES, yet it is held in the minority view because it is not well understood by teachers. Porlan and Martin del Pozo (2004) offered a reasonable explanation as to why it is not well understood, by explaining that although teacher education programs teach the “alternative model,” it is taught in a traditional (i.e., lecture based) format.

van Zee (2006) took the challenge to teach “science teaching” through an inquiry approach and led her pre-service elementary teachers on a four-step process to fully engage in inquiry so they would have an understanding of a full inquiry approach. She chose to do this because of her belief that most had never experienced full inquiry. She
began by having the pre-service teachers ‘inquire into natural phenomena’ related to the sun and moon.

This led into level 2: Prospective teachers inquire into their own learning. Confirming that most had never engaged in an open inquiry, she had them review their initial surveys about their understanding of the moon phases compared to their current understanding based on the ten-week learning period. The students developed a paper reflecting on their development of understanding over time. “Thus, by doing this assignment, they are learning to do scientific inquiry, learning about the nature of scientific inquiry, and learning about inquiry as a method of instruction” (van Zee, 2006, p. 246).

In the third level, pre-service teachers continue the inquiry into how children learn and how their own teaching affects this learning. One of the group’s conclusions about implications for instruction was: “In order to keep students engaged in learning science, teachers should build upon the background knowledge of students and challenge students to look deeper into the subject by further analyzing their observations” (van Zee, 2006, p. 248). This also supports the use of concept interviews and science talks as methods of ascertaining the current level of students’ understanding and building on that knowledge base.

Finally in the fourth level, she had worked with the pre-service teachers in inquiring about her own teaching practices by reflecting on the course throughout the time and providing feedback to the instructor. One comment in particular sticks out, “When are you going to teach us how to teach science?” (van Zee, 2006, p. 251). From
this van Zee realized she needed to be much more explicit in explaining her methodology and reasoning for doing it in this manner. Again, even the pre-service teachers showed resistance to this open-inquiry design as a method for their own learning.

Porlan and Martin del Pozo (2004), using multifactorial analysis on the ISPB of in-service and pre-service teachers, further identified three tendencies about “learning science” which confirmed earlier studies.

1. **Learning by appropriation of meanings.** The pupil’s mind is seen as a tabula rasa that receives information from the teacher and will capture its meaning as long as the pupil is attentive and suffers no mental dysfunction. The communication of content is assumed to be a linear process in which the meanings undergo no alterations and each concept has a single meaning (p. 54).

2. **Learning by assimilation of meanings.** In order to learn, one has to be personally involved in the content of the learning, relate it to what one already knows, and incorporate it meaningfully into the existing cognitive structure. It differs from the previous tendency in the greater degree of importance it gives to the need for the learning to be meaningful to the learner (psychological meaningfulness) (p. 55).

3. **Learning by construction of meanings.** Finally we detect a minority view in which knowledge is not something acquired or assimilated, but constructed (p. 55).

These last two meanings come closest to the NSES definition of inquiry in actively involving the learner in the learning process as opposed to the teacher being the holder of
all knowledge that is then imparted to students. In the second meaning, the emphasis is placed on connections to prior knowledge, which is a highlight of the inquiry process.

Jorgensen (2001) emphasized that “there are no right ways to teach for all learners, and likewise there are no right ways to learn for all learners” (p. 127). Yet the inquiry mode of instruction in science education if implemented by teachers confident in their teaching and willing to be open to student learning and exploration could be a powerful force in moving the United States science education far into the 21st century.

Mastropieri et al. (2001) concluded that students with learning disabilities could benefit from the constructivist classrooms that are utilizing inquiry approaches to science, but they caution that not all special learners will necessarily benefit without the necessary accommodation. Grade level and IQ were the primary determiners of ability to succeed in active, inquiry-based lessons. The research indicates that many students with disabilities, but an IQ of 80 or above will successfully perform in a constructivist environment even though their reading and math scores are below the regular education students in the class. Students with lower IQs did not achieve at the same rate and were frustrated by the constructivist approaches. The researchers recommend that special accommodations made for these learners, including peer helpers will allow them to achieve in inclusion classrooms, thus making inquiry a viable learning tool for all students. Intervention accommodations by adults for students with learning disabilities is also recommended by Palinscar, Collins, Marano and Magnusson (2000) in inquiry classrooms, and includes low-level intervention which could be redirecting the students’ attention by asking them to explain what was happening to high level intervention which could be offering the
student support in recording (writing down) the student’s thoughts and understanding of what was happening if the student appeared to be having difficulty with writing.

Dalton, Morocco, Tivnan and Rawson Mead (1997) found similar results with children with learning difficulties, readily succeeding in inquiry based science classrooms. In the conclusion section, the authors pointed out that the learning varied greatly among the children with learning difficulties, i.e., the top performers were not the “most able” and suggested that further study should be conducted on other characteristics that may have impacted their learning including, “collaboration skills, persistence, acceptance of ambiguity, curiosity, response to errors, and oral communications” (Conclusion, ¶2). These same skills may be what drive most students to succeed in inquiry-based classrooms.

Additional reports also supported the need for introducing and increasing inquiry learning beginning in the earliest grades. Rathbun, West and Hausken (2004) reported on the Early Childhood Longitudinal Study that African-American and Hispanic children already lagging behind white students in kindergarten continue to show this trend through third grade, especially in science achievement. In comparing TIMSS 1997 to TIMSS 2003, although the U.S. improved their international standing in the 2003 test, the improvement was in the basic facts at the lower level, while there were decreased scores from the 1997 to 2003 in the upper level indicators. The 2003 TIMSS test incorporated inquiry at the upper level. And the Science and Engineering Indicators 2006 report also indicated that we need to strengthen students understanding of science inquiry. The Science and Engineering Indicators (2006) drew from other reports including the PISA
(Programme for International Student Assessment) also conducted in 2003. The PISA results, measuring the equivalent of 10th grade performance indicated that students in the U.S. were far below the international trends. The PISA test measures “students’ ability to apply scientific and mathematical concepts and thinking skills to problems they might encounter, particularly in situations outside of a classroom” (National Science Foundation, 2006). If we do not begin teaching science inquiry early on, it will continue to be difficult for students to “catch-up” and we will continue to leave students behind.

**Professional Development**

Science inquiry will only occur if we dedicate resources and time to professional development of teachers and they see the value of inquiry for their students. Support is needed from administrators, teachers and the community at large in order to facilitate such a dramatic shift. Inquiry-based classrooms are slowly evolving but change takes time, but without the support of administrators, community members, teachers and the students themselves, the value of an inquiry-based classroom will not be readily realized. Klein (2001) pointed out that it is essential to recognize that the needs of elementary science teachers are very different than their secondary counterparts.

Schmidt (2001) in explaining the Third International Mathematics and Science Study (TIMSS 1997) offered insight in ways that U.S. students were lacking behind students in other countries. The 2003 Trends in International Mathematics and Science Study (Martin et al., 2004) offered a glimpse that although the U.S. improved in their standings compared to other nations by raising the lower-level performance indicators,
they actually dropped in the higher, more challenging indicators which included inquiry. U.S. curriculums are often categorized as a mile wide and an inch deep and lacking substance. We concentrate a lot of efforts on “covering” materials as opposed to “uncovering” understandings as students attempt to delve into science and math topics. The other problem we face is the diversity of curriculums that are taught. Each of the 501 school districts in Pennsylvania has sole control of what is offered. This is slowly changing with the implementation and alignment of districts to the Pennsylvania Science and Technology and Environment and Ecology (STEE) standards. So far, approximately 150 of the 501 school districts in Pennsylvania have aligned their curriculum with the Science and Technology and Environment and Ecology standards although considering that the standards have been considered Pennsylvania Law for eight years (since 2001), the number should be higher. Evidence from the Final Reports of the Pennsylvania Governor’s Institute for Life Science Teachers (Boomer, 2007, 2006, 2005) showed that the majority of teachers seeking this summer professional development week were not that familiar with the STEE standards when they first arrived. By the end of the institute, their familiarity rose significantly and was retained for the most part when interviewed six months later. This supports the conclusion that less than 1/3 of the schools have aligned to the standards, although Patricia Vathis, Senior Science Advisor and Environment and Ecology Advisor for the Pennsylvania Department of Education, felt that the standards alignment is offering a shift toward a state-wide curriculum (personal communications, September 25, 2007).
Work continues on taking the Pennsylvania STEE standards which are “law” and breaking them into manageable pieces so that teachers can see what the student should be able to accomplish and what the teacher should be doing to assist. This breakdown of the STEE standards has been published for the Pre-K through Second grades. Some states such as Texas, New York and California have had state-wide curriculums for a while, but still face similar problems of trying to cover too many topics (Schmidt, 2001, p. 157).

If more emphasis were placed on offering inquiry opportunities for students and we began cutting down on the “facts” that we attempt to “cram” into students’ brains, we would begin to tap into the natural curiosity that students have and scientists continue to maintain throughout their lives. If our goal is to make students science literate, they need to experience inquiry so they have the opportunity to “understand” the science behind the “processes”. D’Ambrosio, Harkness and Boone (2004) suggested that students also should be surveyed to help determine their perceptions of what is happening in the classroom and this would help guide the professional development opportunities offered to teachers.

Professional development has taken on a new look in recent years. Prior to the current reform efforts, professional development opportunities either consisted of district sponsored, day long, in-service programs usually filled with either a motivational speaker and/or administrators pointing out the latest changes to the professional handbook and/or a university sponsored course. Typically at the district-sponsored workshops, some teachers would attend these in-services with newspaper in hand or grade books and a
pack of papers to grade. Administrative efforts to curb this behavior often fell on deaf ears and veteran teachers pointed out to young recruits that all this “hog-wash” was just a rehash of what has come down before. Klein (2001) found that the traditional in-service rarely effects the teacher’s methods of teaching and indicated the need for an overhaul of in-service programming.

Recent efforts to put a new face on professional development are changing a few minds about the importance of this effort to keep teachers current. Not everyone is willing to change, but little by little school districts are realizing just how important professional development is and teachers are slowly adapting to the change. But what exactly is this new face of professional development? Gibbons, Kimmel and O’Shea (1997) suggested a combination of workshops, orientations, newsletters and weekly observations with at least a two-year commitment as a good model. They also pointed out that collegial support is vital for success.

Guskey (2003) pointed out that there is very little consensus on what constitutes effective professional development, and found “that the research evidence regarding most of the identified characteristics is inconsistent and sometimes contradictory” (p. 749). He reviewed 13 different lists from the past decade and determined that most were “research-based” but was critical of the research since most were survey oriented and only measured teachers’ impressions of effectiveness without highlighting one of the biggest key factors, the ultimate effect on students. Guskey (2003) pointed out only two studies--the National Institute for Science Education (NISE) analysis and an Educational Testing Services (ETS) study--“showed a direct link between their identified characteristics and
specific measures of student achievement” (p. 749). Wenglinsky (2002), in putting together the ETS study, combed the qualitative research databank and found by using “the technique of multilevel structural equation modeling (MSEM)” he was able to correlate higher student test scores with the teacher’s professional development training in higher-order thinking skills in math and science (Hypothesis, Data and Method, ¶ 5). Since then, Banilower (2007) and Banilower, Fulp and Warren (2008) showed a significant improvement in student assessment scores when the teachers engaged in quality professional development conducted over time.

The study from NISE led to the publication in 1998 of Designing Professional Development for Teachers of Science and Mathematics authored by Susan Loucks-Horsley, Peter Hewson, Nancy Love, and Katherine E. Stiles which outlined seven principles of effective staff development for math and science. The second edition, published in 2003, offered the same seven points, but clarified them. This section will outline those seven principles and add two additional ones: Number 8 comes from the National Science Standards, and Number 9 will deal with change and school culture.

The first eight principles were designed specifically with math and science in mind, but I believe can cut across other disciplines. Guskey (2003) on the other hand warned that since the primary research only focused on math and science, the impact on social studies and language arts is not clear.
Nine Principles of Effective Staff Development for Science

**Principle 1:** *Effective professional development is driven by a well-defined image of effective classroom learning and teaching* (Loucks-Horsley, Love, Stiles, Mundry & Hewson, 2003, p. 46).

Since the primary focus of professional development should ultimately be the impact on student learning, knowing what works effectively in the science and math classroom is critical for teachers. In addition, there must be a belief that all children can learn math and science given the right opportunities that include inquiry learning, experimentation, problem solving, and applying this to knowledge (Loucks-Horsley et al., 2003). Borko and Putnam (1995) also pointed out that,

> Virtually all reform efforts are calling for changes in our educational system that will help students to develop rich understandings of important content, think critically, construct and solve problems, synthesize information, invent, create, express themselves proficiently, and leave school prepared to be responsible citizens and lifelong learners. (p. 37)

Given the chance, students should be able to delve into science and math, developing clear understandings as opposed to memorizing information and regurgitating it back. In practice this starts with a belief radiating from administrators, teachers, parents and students that students can achieve given the right impetus. This principle focuses on both effective classroom learning and teaching. Active learning environments that stimulate planning, thought, encourage risk taking and are authentically assessed will foster the students’ growth and development as they begin to construct their own knowledge. Jorgenson (2001) used Henriques’ model of Social Constructivism in trying to refine a professional development model and determine that there is no one way of
learning for all students, nor is there only one right way of teaching for all students. Jorgenson also pointed out that if students and teachers are willing to “become tolerant of individual differences in ways of constructing knowledge, exciting growth and learning results” (p. 127).

In order to assure that we are teaching the students in the most effective way, it is also necessary to assess their prior knowledge. Sink (2001) offered the voice of experience as an elementary teacher when she explained that she came to the realization that she needed to assess students’ knowledge prior to embarking on lessons. Professional development opportunities should encourage pre-assessment activities and planning for effective instruction. Ideas such as concept interviews and science talks could be employed in this realm.

In addition, post assessments to determine effective instruction needs to be emphasized. Many researchers are encouraging more teachers to not just depend on traditional forms of testing to make the determination of what students have learned (Lewis, Perry & Hurd, 2004; Smith & Desimone, 2003). Jorgensen (2001) promoted the idea of developing valid forms of assessment that link to the new strategies being promoted and to determine the “effect of assessment formats on student learning” (p. 129). Traditional forms of assessment, i.e., multiple choice testing, may not be accurate pictures of effective learning and teaching, but rather just examples of what the student has successfully stored in short term memory for recall for the test.
Principle 2: Effective professional development experiences provide opportunities for teachers to build their content and pedagogical content knowledge and skills and examine practice critically (Loucks-Horsley et al., 2003, p. 46).

Science is dynamic and the opportunity to update their own content knowledge is critical to keep teachers of science on the “cutting edge” of new information. In addition, understanding how different children learn is critical as we move away from the traditional methods of lecturing and trying to pour all the science knowledge into empty vessels. Garet, Porter, Desimone, Birman and Yoon (2001) pointed out that “many teachers learned to teach using a model of teaching and learning that focuses heavily on memorizing facts, without also emphasizing deeper understanding of subject knowledge” (Introduction, ¶ 3). Davis and Krajcik (2005) suggested that the development of curriculum material must consider the learning of the teachers so they can further develop both content and PCK and further suggested that Bruner promoted this in 1960 and even earlier.

Foster (2004) reported on a program she and others started in 2001 entitled, “Learning through Teaching in an After School Pedagogical Laboratory (L-TAPL).” Designed to improve the teaching strategies and pedagogical understanding of urban teachers with minimal practical experience, she and her fellow researchers found that they fulfilled the second goal of the program, “teacher learning is enhanced and facilitated when programs are organized around the best principles of adult learning: when teachers are given sustained opportunities to experiment with and receive advice on innovations; are given the chance for in-depth learning, inquiry, and reflection; are able
to collaborate with professional peers inside and outside school; and have access to external researchers” (p. 403). Loucks-Horsley et al. (2003) reported that when professional development opportunities are directly tied to high quality curricular materials, the teachers are willing to adjust their teaching. Given the opportunity to work with curricular materials specifically designed to enhance student learning, teachers will begin to not only further develop their own content knowledge, but will experience the pedagogical understanding that students face.

Lieberman and Miller (1999) suggested that schools where they are focusing on research findings, doing self-reflection and applying a systematic approach to inquiry, teachers are finding themselves willing to change (p. 21). Lieberman and Miller (1999) went on to say that teachers should be continuing learners and actively engaging in action research to determine the answer to the question, “How do students learn?” (p. 21). By actively engaging in action research that is critiqued and shared with colleagues, teachers will fulfill the third part of this principle of examining content critically as they focus on how the students are learning.

**Principle 3:** *Effective professional development experiences are researched based and engage teachers as adult learners in the learning approaches they will use with their students* (Loucks-Horsley et al., 2003, p. 47).

Teachers have traditionally been taught in lecture format and are comfortable with this mode of transmission, assuming since it worked for them, it will work for their students. Unfortunately most students do not learn in this manner. Lecturing about a constructivist approach to teaching is also ineffective. Teachers need to experience
inquiry learning and acknowledge the “discomfort” of not having all the “right” answers in order to understand the effectiveness of a constructivist approach to learning.

Smith and Desimone (2003) questioned the effectiveness of professional development based on the current research information. They suggested that more data need to be collected regarding how teachers themselves learn. They saw great potential for professional development, but they did not yet see the evidence. Foster’s (2004) program with urban teachers should add to the evidence needed to satisfy the critics.

Kluger-Bell (2000) reported on three inquiry-based activities for teachers conducted by the Exploratorium Institute for Inquiry. The activities gave teachers the feel for different formats of inquiry, including “a guided worksheet activity; a challenge activity and an open exploration activity” (p. 40). Three groups were formed and assigned different starting activities all working with foam. The guided worksheet group was assigned the task of whipping foam (using dishwashing soap and water) in two bowls. One was whipped 200 times and the other 600 times. The group was told to compare the results and move on to “supporting” the foam on a stick. The second group began with a challenge activity to build a 12-inch high tower of foam. They knew what they were to do, but no further directions or advice was offered. The final group was assigned the task of finding out everything they could about foam and what makes it strong. This freedom to explore was unfamiliar to some of the teachers; some loved the idea and jumped right in, others were very uncomfortable and wanted specific directions to follow. Seeing this, the instructor guided them a bit in finding something they might want to try and explore. All three groups eventually went through all three activities that
were all built around the same theme of foam. Although some were at first frustrated, all groups came away experiencing three forms of inquiry science in a way they never considered before. The discussion that ensued allowed the teachers to realize that there is a continuum of inquiry and that it is not always feasible nor advisable to jump into a totally student self-directed activity until students have a comfort level with this experience. This concept is supported by the National Research Council’s publication, *Inquiry and the National Science Education Standards* (2000).

The teachers, after actually experiencing different forms of inquiry themselves, were better able to take those lessons back into the classroom and design experiences for their own students that eventually would allow the students to venture forth into an open-exploration activity. Again, time must be allotted for teachers to be able to design and prepare these experiences.

**Principle 4: Effective professional development provides opportunities for teachers to work with colleagues and other experts in learning communities to improve their practice** (Loucks-Horsley et al., 2003, p. 47).

Desimone, Porter, Garet, Yoon and Birman (2002) conducted a longitudinal study and identified six characteristics of effective staff development. At least two of their identified best practices are summed up in this principle, namely a “reform type (of activity) such as a study group, teacher network, mentoring relationship, committee or task force, internship, individual research project, or teacher research center” and being “actively engaged in the meaningful analysis of teaching and learning” (Results from Our National Study, ¶ 3).
According to Kelleher (2003) the opportunity to work with colleagues in lesson study, case studies, examination of student work, and designing inquiry based lessons, must also be offered as a daily part of the day and administrators and school boards need to re-assess their investment in professional development opportunities. Little et al. (2003) also pointed out the benefits of bringing teachers together to review student work and highlights that there is some evidence that this type of review may impact teaching and student learning. Their research is dedicated to showing the specific practices that have been proven effective such as:

1. Allow teachers the time to meet together and focus on student work
2. Actually bring student work to the table for discussion
3. Structure the discussion in a very specific manner. (p. 187-188)

Other researchers highlighted the use of critical friends group and the tuning protocol (Easton, 2002; Bambino, 2002; Routman, 2002).

Little et al (2003) pointed out drawbacks to a number of these programs that put student work in front of fellow teacher colleagues: 1. Teachers felt a greater sense of discomfort when their students’ work was being discussed because they viewed the work as a direct reflection of their teaching and 2. They were not sure what to highlight in bringing forth the student’s work. Although Little, Gearhart, Curry and Kafka (2003) quickly pointed out the benefits of a protocol system, one particular group in their study still struggled with this problem due to workloads; they had to decide quickly what to present and how to explain it in the short time given. This lack of planning time to reflect on what to offer presents itself as a drawback.
Watanabe (2002) explained that a lesson study is a research lesson that a number of teachers develop together. Taking a lesson that typically causes problems for students, the teachers try to determine what the research suggests and then attempts to put these components together in a well-constructed lesson. One of the teachers teaches the lesson while the others observe and take notes on the student reactions and the progression of the lesson. Afterwards, a discussion is held where the teacher offers a brief explanation and then the observers review what they saw, based on their research, and what they felt worked and did not work (Inquiry Groups, ¶ 2 and What Research Lessons Do and Don’t Do, ¶ 1, 3). One of the key factors is that the group may not be able to determine which way is the most effective based on just one lesson, but the “participants left the lesson study meeting with new insights into how to teach this unit” (What Research Lessons Do and Don’t Do, ¶ 1, 3). Lewis et al. (2004), a proponent of the “lesson study” method imported from Japan, pointed out that there are “seven steps that must be followed for success with the lesson study model: increased knowledge of subject matter, increased knowledge of instruction, increased ability to observe students, stronger collegial networks, stronger motivation and sense of efficacy, and improved quality of available lesson plans” (p. 19).

Another approach might be the opportunity to plan and design inquiry-based lessons with colleagues and share these lesson ideas prior to teaching and then offering time to go back and reflect. Time becomes the major factor here, but if given the opportunity and encouragement to incorporate inquiry lessons over the course of the year,
and the opportunity to plan, discuss, debrief, and share what went right and what needs to be improved during the year, teachers will become more comfortable with the challenge.

If small groups of teachers (perhaps no more than five) could meet to discuss lesson studies, case studies, inquiry designed plans, or examine student work, the impact on students could be immense. A facilitator would need to be appointed (or elected by the group) and a time commitment by the teachers and administrators needs to be made. If the meetings must go beyond the contracted school day, monetary incentives might be in order to maintain the commitment of the group.

Ideally this would occur on a daily basis, but in reality if time could be set aside once a week for this meeting the benefits would outweigh the costs. Chokshi and Fernandez (2004) in their surveying of lesson study groups found that most groups felt the process to be extremely rewarding and were able to meet at least once a week and sometimes even during the day. They recommend since time is a factor, assigning roles and distribution of materials for review ahead of time will assist in maximizing the time. Administrators also play a role in allowing these groups to meet by hiring substitutes or allocating funds in other ways.

Poglinco and Bach (2004) offered another perspective of this principle when they shared their research on the role of teaching coaches in schools and found that although it can be a great idea in theory, if it is not carefully conceived and carried out, it can become very ineffective and a waste. If it is carefully designed the impact can be tremendous, especially on the individual level as coaches worked side-by-side in classrooms with teachers and co-taught lessons, modeling a variety of instructional
techniques. “Of all the techniques coaches employ, modeling instruction in individual classrooms is most likely to result in modifications in instructional practices and adherence to the instructional formats” (p. 399). D’Ambrosio et al. (2004) demonstrated this claim by using graduate assistants specifically trained to serve as coaches and to model instructional techniques in assigned classrooms.

**Principle 5: Effective professional development experiences support teachers to serve in leadership roles** (Loucks-Horsley et al., 2003, p. 47).

Teacher leaders can serve in a coaching capacity within their school districts, mentoring young teachers and other teachers interested in moving into inquiry settings. They can team teach and/or serve as resource people to help foster a collegial atmosphere as the district moves toward incorporating inquiry learning. In addition, they might serve as the facilitators for lesson study groups. Similar to the mentor program offered a number of years ago, this form of service within the district would allow the teacher-leader to break out of the isolationism of teaching and develop professionally, but some warn that not all teachers who are outstanding with students will be effective leaders (Loucks-Horsley et al., 2003; Poglinco & Bach, 2004). The teachers chosen to lead must be carefully selected and trained. Unfortunately, they easily can become targets of colleagues if a professional culture has not yet been established within that school or district (Loucks-Horsley et al., 2003).

The training of these leaders should mirror the identified principles of effective professional development. “It should be long term and planned, focus on student achievement, job-embedded, supportive of reflective practice, and provide opportunities
to work, discuss, and problem solve with peers” (Loucks-Horsley et al., 2003, p. 99). Teaching coaches can be pulled from the ranks of the staff and if trained properly and given adequate direction, can prove to be valuable members of the professional development team (Poglinco & Bach, 2004). Johnson and Kardos (2002) pointed out that new teachers are begging to have experienced colleagues share ideas, “take their daily dilemmas seriously, watch them teach and provide feedback.” If we do not provide this kind of support, we will continue to experience the high attrition of young teachers that are not in the classroom long enough to know if they really like it or not (Wanted: School-Based Professional Development, ¶ 1).

One of the biggest drawbacks to these ideas is that it takes time and additional staff. Time is limited until we begin to realize the essential nature of offering teachers these opportunities. Additional staff members may strain a budget, but when the ultimate benefactors are the students these ideas must be considered. Another possibility to consider is developing a couple teacher leaders simultaneously for each subject area and have them work part time as a teacher leader, but maintain some regular classroom time with their own students.

**Principle 6: Effective professional development experiences provide links to other parts of the education system** (Loucks-Horsley et al., 2003, p. 47).

Time and money are always major concerns as districts look to spend these resources in the best way possible. Sometimes, initiatives that could cut across all or similar disciplines are only focused on one discipline and the various disciplines become splintered in their professional development mode. A clear vision of the school district’s
direction is needed and a long-term plan designed by representatives of all parties involved (including taxpayers) needs to be outlined and presented to all for understanding where the district is heading. By opening the lines of communications and sharing the long-term vision, programs with similar goals could potentially be combined reducing the monetary and time costs. Zmuda, Kuklis and Kline (2004) suggested, “It is not the number of innovations addressed in the staff development plan but rather the purposeful linkage among them that makes systematic change possible and manageable” (p. 19).

Stein, Smith and Silver (1999) identified the need to link to other areas, pointing out in the past that “subject matter specialists typically design professional development that focuses on content issues with little or no attention to organizational context; educational leadership specialists, on the other hand, tend to focus on organizational issues with little attention to subject matter” (Consideration of Organizational Context, ¶ 4). If we could combine the philosophies of both camps, staff development offerings would be a lot more dynamic and user friendly.

Professional development opportunities should be linked to other initiatives with the district or school and be tied to the district’s or state’s curriculum and assessment goals. It is also vital that community support is evident to move forward (Loucks-Horsley et al., 2003). Probably the most important but often overlooked aspect is the community, including parents of students in school and other taxpayers. They are concerned as to how their money is being spent, especially for “in-service” programs and why that time is not being spent with students. They also express concern about the rigors of the curriculum and are not sure if new ideas like inquiry science should be
allowed to be used on their students (Loucks-Horsley et al.). Opening the line of communications is the only way to ensure that parents and community members will support the initiatives. This is more effective when the community can see how these initiatives are directly linked to district and state goals for the improvement of student learning.

**Principle 7: Effective professional development experiences are designed based on data that determine their focus and priority as they relate to student learning, and they are continuously evaluated to ensure a positive impact on teacher effectiveness, student learning, leadership and the school community** (Loucks-Horsley et al., 2003, p. 47).

This is one that has changed slightly from the first edition in 1998 because now the emphasis is placed on the use of data to make the determination of the impact on student learning. Data driven decision-making is having a major impact on school districts as they review the data from standardized tests and other sources. The key is that additional sources of information are used and there is not just a sole reliance on standardized formats.

The reflective aspect is also a key component in that professional development programs must be continually evaluated to make sure that they are serving the target population that they are intending and that all stakeholders, including community members are kept abreast of developments as they occur.

An additional opportunity for data collection and the impact on students would be to encourage teachers to design a teacher action research project or inquiry project in
their own classrooms. The results of such projects should be shared and discussed with the whole learning community. Teachers willing to embark on this venture need to feel administrative support and if they could join a research “support” group this would encourage them to carry on in their endeavors.

**Principle 8: Professional development for a teacher of science is a continuous, lifelong process** (National Research Council, 2006, p. 57).

I would say that all teachers, no matter what their discipline or area of certification must adopt this philosophy of lifelong learner in order to stay fresh and energized in the classroom. Professional development, if given the financial resources and time commitment needed by districts and supported by communities, will become the impetus for change needed in our ever changing society. The school of the twentieth century should not be the model for the school of the twenty-first century. We need to move ahead and create school communities where all students are valued for their abilities and all teachers see the value in each individual student and work toward nurturing each child’s potential to its fullest.

Teachers should be encouraged to attend professional development opportunities offered through intermediate units, college and universities and professional organizations, but the learning cannot stop there as teachers need the support and acknowledgement of fellow teachers and administrators as they try new approaches. The ability to work with others on an action research or inquiry project for the improvement of teaching and ultimately the success of students require the commitment of extended time and financial resources from districts.
Principle 9: Effective staff development programs will identify the importance of understanding both school culture and the complex nature of the change process.

Any time you are dealing with a change of position or change of philosophy there will be a block of resistance. Teachers are very resistant to change and most professional development opportunities (formerly called primarily in-service training) are met with a lot of skepticism. Breaking through this barrier may prove to be the largest challenge for any professional developer. It should be noted that a number of authors pointed out that what may work in one instance does not necessarily work everywhere. Professional development coordinators need to consider the climate and culture of the school district and plan accordingly. In addition, change is difficult for any culture, but especially it seems teachers. Lieberman and Miller (1999) pointed out, “conflict is inevitable in any major change effort” (p. 24). Thompson (1997) acknowledged that, “schools must learn to embrace uncertainty as a necessary part of growing” (p. 14). If the school climate is not healthy, change will not be allowed to happen.

The culture of the school must also be considered before implementing any type of radical change. Zmuda et al. (2004) suggested that the first step to continuous improvement is to “identify and clarify the core beliefs that define the school’s culture” (p. 18). In explaining this, the authors pointed out,

Some faculties may hold achievement in the academic disciplines as primary; others may believe that the social and emotional development of students is primary. Both are core beliefs and drive teacher support for the status quo or the need to change the status quo.” (p. 18)

If someone attempts to create a change without identifying the core beliefs that drive the culture of the school, they are setting themselves and the school up for failure.
Loucks-Horsley and Stiegelbauer (1991) defined the Concerns-Based Adoption Model (CBAM) as a program that demonstrates individual reactions to change and the negative implication that it might have on the professional development opportunities. According to the authors, the CBAM program was established in response to programs being implemented to address “communication, problem-solving, and decision-making structures in schools, and about their climate” without addressing the actual teaching and learning and the impact that it was having on individuals (p. 16). The implications were that teachers were being forced into teaching practices that they did not necessarily buy into. Change did not occur in these situations, but frustration and skepticism for new programs was rooted.

How Should a District Get Started?

There are a number of programs available to assist districts in their planning process, including websites, programs and books from the Association for Supervision and Curriculum Development (ASCD), but repeatedly authors warn that what works for one district may not work for another. As an example, Thompson (1997) explained the RPLIM model, which stands for Readiness for Development; Planning for Staff Development and School Improvement; Learning New Roles and Practices; Implementation of New Practices and Maintenance and Monitoring (p. 20). Based on the experience of those using this model, Thompson went on to identify key components that will help to ensure success with a new professional development program including:

1. Securing the support of the superintendent, board and community members since money and time commitments will become costly factors. Part of this
commitment should also be the realization that mistakes will be made and that quality change and improvement takes time (Thompson, 1997, p. 25).

2. Identification of key leaders who will participate in the initial training phase and serve as “site facilitators who will have the responsibility for nurturing and leading the improvement processes at individual schools.” The members should include an administrator, a teacher and a parent and some districts also include paraprofessional representation, students and community leaders (Thompson, 1997, p. 26).

3. A planning team is appointed which is led by the site facilitators and might include as many as twenty individuals, including staff, administrators, parents, students and community leaders that must first build “team” support and learn to keep communications open among all participants and stakeholders. Ultimately this group will “focus the vision on first steps.” The process to this point will take up to a year to accomplish (Thompson, 1997, p. 26).

4. The planning stage is next with each “priority goal … assigned to a different design team.” Design teams are created based on levels of expertise and interest levels and are charged with determining the best practices and materials or programs that are needed to accomplish the goal. These plans are given back to the design team for further study and communications with all stakeholders (Thompson, 1997, p. 27).

5. Implementation comes next and is literally putting the plan into action and includes, “follow-up to learning events, peer coaching systems, and frequent
discussion, reflection, and adjustment to the blueprint” (Thompson, 1997, p. 29).

6. Last, but not least, is maintenance and monitoring. Thompson warns that this is usually the most overlooked step, but is the most valuable. “Many of our attempts at innovation in the last few decades have been discredited because they have been evaluated without truly being implemented” (p. 29).

Klingner (2004) offered a slightly different perspective and summed up the lessons learned in trying to implement professional development in a district: “(a) a partnership cannot develop without strong grassroots support from teachers; (b) translating research knowledge into a form that is useful for teachers is a major, time-consuming task; (c) teacher participation needs time to grow from year to year; and (d) it is essential to help teachers learn to link changes in practice directly to changes in student performance” (Researchers Bridging the Research-to-Practice Gap, ¶ 2).

Although Klinger and Thompson differed in their approach to what is most important, I would offer that without the grassroots support of teachers, the idea, even if supported by the administration, will not get very far. All stakeholders must work together to create a vision of where they see the school or district in five years. All the programs take time to plan, implement and evaluate. One of the most crucial components of any change program is communications among all stakeholders. If communications breaks down and is not fixed, the program is doomed for failure.

Professional development in schools today must be thoughtfully planned out conducted and evaluated in order to be successful and not just more “hogwash” that has
been rehashed time and again. All stakeholders must be represented in the planning, implementation and evaluation process in order for the change to take place. Change takes time. Change will not happen overnight and is very difficult for people to accept, but if we want to improve schools for the 21st century, we need to be willing to participate and become active members of the changing community. It is time for teachers to unlock their classroom doors and for administrators and community members to be actively involved in the classrooms and beyond.

The literature is rich with examples and ideas of why we need to support science inquiry and the need for on-going training of elementary teachers to encourage their teaching of science in an inquiry fashion. Duschl et al. (2007) in Taking Science to School wrote in Conclusion 13:

To create a successful science classroom, teachers need to modify and adapt curriculum material so as to design instruction that is appropriate for a particular group of students at a particular time. Making these kinds of modifications to achieve effective instruction requires knowledge of science, knowledge of how students learn science, and knowledge of how to plan effective instruction. Many K-8 teachers have insufficient knowledge in one or all of these areas and need ongoing support to develop it.

This is where the survey described in Chapter 3 will come into play. We must know where teachers are in their current understanding of inquiry learning and teaching and the impact of other factors on their teaching. In addition, the availability and willingness for teachers to participate in professional development must be assessed.
Chapter 3

METHODS

Introduction

Elementary teachers tend to be broad-based specialists and may not have confidence regarding their content knowledge to encourage students to explore on their own in a science setting. Many teachers learned primarily in a lecture dominated teaching environment and are comfortable with this teaching approach, which they often emulate. It is important that elementary students be given the opportunity to explore and “discover” answers on their own with guidance from the teacher. But if teachers are not comfortable or familiar with this style of science inquiry learning, they are not readily going to adopt it in their classrooms. According to Fulp (2002), a majority of “elementary school teachers do not feel equally qualified to teach all academic subjects, with preparedness to teach science paling in comparison to mathematics, language arts and social studies” (p. 5). Weiss et al. (2001) also reported, “in science, elementary teachers are less likely than middle and high school teachers to feel prepared to develop students conceptual understanding of science, provide deeper coverage of fewer science concepts, make connections between science and other disciplines, lead a class of students using investigative strategies, and to manage a class of students engaged in hands-on/project based work” (p. 9).
Purpose and Research Questions

The purpose of this study was to determine current Pennsylvania elementary school teachers’ perceptions and views of inquiry as defined by the National Science Education Standards (NSES) and advocated by the Pennsylvania Science and Technology Standards (PSTS). In addition, the study identified approaches to professional development that would “fit” the elementary teachers’ preferences while achieving the goal of introducing and implementing more inquiry within elementary science instruction.

The over-arching research questions being addressed are:

1. Do Pennsylvania elementary school teachers define science inquiry in a similar way as it is defined in the National Science Education Standards? The sub-questions are:
   a. How familiar are Pennsylvania elementary school teachers with the Pennsylvania and National Science Standards, especially in relation to inquiry?
   b. Do Pennsylvania elementary school teachers recognize the definitions of science inquiry used in the National Science Education Standards (NSES) and Pennsylvania Science and Technology Standards (PSTS) when the definitions are stated literally?
   c. Do Pennsylvania elementary school teachers recognize the definitions of inquiry used in the National Science Education Standards (NSES) and Pennsylvania Science and Technology Standards (PSTS) when the concepts are presented in context?
2. What are the relationships between self-reported familiarity with NSES, recognizing NSES definitions of science inquiry literally and recognizing NSES definitions of science inquiry in context?

3. To what degree do Pennsylvania elementary school teachers agree with accepted principles of effective professional development?

4. To what degree are Pennsylvania elementary teachers willing to participate in professional development activities that reflect accepted principles of effective professional development when the professional development is focused on science inquiry?

**Researcher’s Role**

At the time of the survey, I was employed as an eighth grade middle school science teacher who did in-service programming on inquiry science for elementary and middle school teachers for my own district. In addition, I was also serving as an adjunct instructor of elementary science methods at a local university. My district was within the targeted survey area, so they were removed from the actual survey to ensure that my prior in-service programs had not biased the results.

My own eighth grade physical science classes were designed around a mix of approaches from guided through open-ended inquiry and labs that could last days through a couple weeks as students worked their way through the latest “problem.” I strongly believe that inquiry should be a primary focus in ALL science classrooms throughout all grades. Inquiry allows students to explore and explain their own results, challenging each
other and realizing that the inquiry process is just as important if not more important than finding the “right” answer. If students are allowed to fully engage in inquiry science, including evidence-based discourse, they will discover their passion for finding evidence and will also find their voices as they debate the findings. Inquiry science takes students to the level of application and synthesis and not just memorizing “facts” from a text.

As far as professional development, I recall attending many one-day workshops and each year a new “theme” was presented as the focus for the year. As a teacher, I really did not see the value of the one-day in-service programs especially if it was a district-wide or school-wide meeting with an individual lecturing. As I continued on my own coursework, I began to understand the value of long-term (over a 3–5 year time period) professional development with a common theme. I also realize the essential need that the teachers are a crucial part of the decision making regarding the professional development theme. In addition, I feel that the one-day in-service programs are appropriate for introducing new ideas, but it is essential that follow-up be conducted and preferably initiated by small groups of teachers working together to move the theme forward. Without this, the one day in-service may be considered a waste of time. All teachers should be involved in this initiative for the district to fully benefit.

**Defined Target and Accessible Population**

This study focused on an intermediate unit in south-central Pennsylvania with a diversity of rural, suburban and urban school districts reflecting communities of diverse socio-economic status. It is the judgment of the researcher that the diversity of the
teachers in terms of professional experiences and educational preparation across the 24 school districts is a fair representation of Pennsylvania’s elementary school teachers. The 24 school districts in the intermediate unit included 96 elementary schools and approximately 1610 “regular” elementary classroom teachers. The term “regular” elementary teacher refers to those teachers who teach the general education curriculum and excludes teachers identified as special education, or specialists like art, music and physical education teachers.

In May 2005, I surveyed elementary schools in a south-central Pennsylvania intermediate unit. Some of the 96 elementary schools only include grades K-4 and a few include K-8 but the majority of the schools were K-5 programs. If a school only had K-4 grades, only those teachers were included in the count since the 5th grade teachers were under the middle school program. For the schools with K-8 grades, only the K-5 grade teachers were included in the count in order to maintain consistency. All special teachers including identified teachers of art, music, health and special education were excluded from the teacher count.

Using the Internet, I accessed each district’s website and downloaded the staff directories. Some elementary schools within the district posted staff directories and others did not. In a few of the elementary schools, directories of all school personnel were posted but teachers were not identified by their positions. Twenty-three schools were contacted by phone to ascertain the number of regular elementary education classroom teachers. With all this information it was determined that 1610 regular education elementary teachers were in the defined target population (Huck, 2000).
According to Cochran (1997) the ideal sample for a population of 1610 is 313, but only 1093 teachers’ names were available thus representing the accessible target population (Table 2). The number of teachers eliminated due to a lack of any contact information was 433 teachers or 27 percent of the defined target population. I was employed by a school district at the time of the survey, and my own district was within this intermediate unit, so those teachers were also removed from the defined target population. These 84 teachers represented an additional 5% of the population that was excluded from the defined target population.

The elimination of 32 percent (517) of the defined target population may be viewed as a limitation to the study, but there were other schools within the study that exhibited similar geographic and socio-economic strata. For example, within a district some of the elementary schools did not offer a staff listing, but other elementary schools within the district did include a staff listing, thus allowing for teacher representation within each of the 24 districts in the IU.

**Study Sample**

Each mailed survey cost the researcher about $1.65 per survey, so based on a financial consideration, I chose to only survey approximately 2/3 of the 1093 teachers in the accessible population resulting in a sample of 729 teachers. Teacher lists from each school were compiled, and systematic random sampling was used. I eliminated every third elementary teacher on each school list.
Table 2. Projected Target Population versus Accessible Target Population.

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<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Projected Target Population</td>
<td>1610</td>
</tr>
<tr>
<td>Accessible Target population (access to teacher names)</td>
<td>1093</td>
</tr>
<tr>
<td>Sample size (66.7 % of accessible target)</td>
<td>729</td>
</tr>
<tr>
<td>Responses</td>
<td>238</td>
</tr>
<tr>
<td>Usable responses</td>
<td>228</td>
</tr>
</tbody>
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Data Collection

In order to facilitate communications and response rate, I individually hand-addressed a letter to each teacher in the sample as opposed to using a general mailing to a school. In addition, after the initial mailing, email was the primary form of communications with teachers selected to participate, and three general e-mail reminders to return the survey were sent. Of the 729 surveys sent on May 4, 2005, I had email addresses for 503 of the teachers, and to those teachers I sent three separate emails. The initial email was sent within two days of mailing the survey and elicited a number of email responses which I responded to individually; the next two emails were friendly reminders sent at the end of week 2 and week 4. In addition, schools with teachers that only had staff listings but no email contacts were included so, 226 U.S. postal mailings went to those teachers with a separate note asking them to please respond. Telephone calls were made to these schools to let them know that a survey was coming and to ask
for their cooperation in encouraging teachers to respond to it. These were sent in care of the administrative assistant and a candy bar was included for the administrative assistant to thank her for distributing the surveys. A follow-up phone call was made to the schools at week five in the hopes of soliciting the last few surveys.

In order to achieve a high rate of return response each mailed survey included a postage paid, pre-addressed envelope, a letter explaining the survey and two first class U.S. postage stamps as an incentive to complete and return the survey. Of the total 729 surveys sent, 238 were returned with 228 (31%) of them being completed and included in the analysis. This represented less than the desired 313 as prescribed by Cochran (1997), but is still considered acceptable.

In order to check for response bias, a wave analysis as described by Creswell (2002) was conducted at the end of the first, second, third, fourth and fifth weeks (p. 411). A wave analysis of responses for each week was conducted on the open-ended questions because I felt this is where the bias, if any, would be exhibited. The results of the wave analysis using crosstabs and chi square in SPSS indicated there was no significant difference association in any of the responses to the open-ended questions by response time frame.

Survey Instrument Development

When deciding on the most appropriate means of collecting data I decided on a survey since the research questions are primarily attitudinal or perception based. In addition, I was interested in obtaining as many responses as possible to quantify the
attitudes of those being surveyed. I reviewed two attitudinal surveys, the Views of Science Inquiry developed by Norman G. Lederman (personal correspondence, February 2004); and the Inventory of Scientific and Pedagogical Beliefs (ISPB) (Porlan & Martin del Pozo, 2004). Neither provided the information needed to answer the research questions, so I developed my own instrument and revised it after the initial pilot testing. Additional survey questions were created after reviewing the National Science Education Standards continuum for implementing inquiry (NRC, 2000, p. 29).

Creswell (2002) cautioned that attitudinal surveys must be “carefully designed so as not to bias responses and to encourage participants to answer questions honestly” (p. 173). In addition, Creswell used a chart outlining the “Steps in Developing or Constructing an Instrument” adapted from a flowchart from Benson and Clark (1983), which defined the four phases needed to develop an instrument including: “Phase I: Planning; Phase II: Construction; Phase III: Quantitative Evaluation; Phase IV: Validation” (p. 179). The phases include pilot testing, rewriting and running additional pilot tests to establish validity and reliability.

A cross sectional survey design was chosen because, “This design has the advantage of measuring current attitudes or practices” (Creswell, 2002, p. 398). I chose the format of a mailed questionnaire since I would be able to reach a wider geographic population of individuals in the target population. In addition, it is an economical way to contact and assess the opinions of a large number of people. I wanted as much input from teachers as was feasible considering the scope and the timeframe. Two disadvantages of cross-sectional surveys are pointed out by Creswell (2002), including
the concept that individuals receiving the questionnaire may not have an interest in the topic and may choose not to participate.

To combat this, Creswell advocated providing small incentives for participants. Each of the randomly selected participants received two first class postage stamps as a small incentive. In addition, I decided to hand address each envelope with the teacher’s name and school address to make a more personal connection. This eliminated some randomly sampled schools that did not identify and/or provide staff listings, but similar schools with similar geographic and socio-economic status were included.

Pilot Test

The second disadvantage defined by Creswell was that questions about statements may arise, but cannot be clarified for the respondent. To address this concern, Creswell recommended pilot testing the questions and receiving written critiques about the clarity of questions. This was accomplished by pilot-testing the original questionnaire during the Governor’s Institute for Life Science Teachers (July 2004). Twenty-four elementary teachers (100%) attending the institute volunteered to complete the survey and provide written critiques of the questions/statements including comments regarding the wording and ease in completing the survey. After examining the feedback, a number of questions were deleted since it was determined that they either were confusing or did not focus on inquiry. Other questions were reworded to clear up possible misinterpretations. Teachers participating in the pilot received a candy bar for their assistance. This minimal incentive
is useful in obtaining teacher participation in the pilot and is recommended by Creswell as an additional way to enhance participation (p. 410).

**Validation of Teacher Survey Items**

Initially three surveys were prepared: one for middle school teachers, one for elementary teachers, and one for elementary and middle school students. The Office of Research Protection at The Pennsylvania State University approved all research procedures (Appendix A). After discussion with the doctoral committee, it was decided to focus only on the elementary teacher survey. To establish content validity, William Trochin (2004), a Professor of Sociology at Cornell University, suggested a modified approach for assessing content validity by identifying a panel of experts and asking them to review the survey for content validity.

The original survey was reviewed by members of the 2004 advisory committee for the Governor’s Institute for Life Science Teachers, including one professor of chemistry; two high school teachers both with PhD degrees in science education (both dissertations addressed inquiry science as defined by NSES); a middle school science teacher who also serves as her district’s science department chair and has a primary focus in inquiry science teaching; and two elementary teachers both recognized for using inquiry in their science lessons. Since this institute was charged with teaching life science using inquiry as the primary mode of instruction, they could offer valid comments in reviewing the survey instrument in light of the state and national science standards in relation to inquiry. The advisory panel used the definitions of inquiry learning as defined
by the National Science Education Standards and Pennsylvania Science and Technology Standards as their basis for reviewing the survey. This is consistent with Creswell’s (2002) explanation of content validity when he explained that typically a researcher will find a panel of judges to review the questions/statements. The advisory committee offered numerous suggestions about the wording of various statements in order to guard against possible bias and suggested removal of statements that were inconsistent with the survey needs. After thoroughly reviewing and discussing the survey in light of NSES, they felt the survey was a content valid instrument addressing a wide range of ideas without being biased. They recommended removal of some questions including the “types of journals/magazines read” as being irrelevant to the study. In addition, the panel reviewed the statements for clarity in wording, grammar and content and their suggestions were incorporated. After the instrument was revised, it was submitted to the doctoral committee and additional suggestions were offered. Numerous versions were developed and a second pilot testing of the questions occurred with a convenience sampling of the elementary teachers (K-5) within my own school district.

In addition, a second panel of experts was asked to review the revised survey in order to further establish content validity (Trochin, 2004). The overarching question addressed was, “Do the statements on the survey reflect the concept of teaching science as inquiry (as defined by the NSES)?” In addition, the panel was asked to review the statements in composite forms that differentiate between traditional and inquiry approaches. The composites are consistent with the 2000 National Survey of Science and Mathematics Education (Weiss, 2001). The committee was asked to judge if the
statements were fair statements in identifying traditional versus inquiry approaches (Trochin, 2004). The second panel of experts consisted of a professor of science education, the state science advisor, two doctoral candidates currently pursuing degrees in science education and a practicing middle school teacher with a masters degree in science education. This panel agreed that the survey instrument was addressing the issues, but expressed concerns about the composite statements, namely saying they added unnecessary length to the survey without further addressing the issues. Based on their suggestions, the final survey did not include any statements from the composite listing.

Reliability

The first pilot test of the survey was a convenience sampling of attendees attending a weeklong residential professional development program held in Pennsylvania. A frequency analysis of their responses was examined using SPSS. Subsequently ambiguous statements were modified and further revisions were made after consultation with the doctoral committee. After numerous revisions, an additional pilot testing was conducted using my own school district’s K-5 teachers, after receiving permission from the district superintendent. This pilot test information was analyzed using SPSS to establish reliability of the instrument. Eighty-four surveys were distributed and incentives of candy bars were offered for completion of the survey. An email informing participants the survey was coming preceded the mailing. A second email reminding the teachers to return the survey was posted a week later. Forty-three people returned the survey for a 51 percent return rate.
The reliability of the summated Likert score was computed using Cronbach’s alpha, a measure of internal consistency. Seven of the 43 people were not included in the reliability analysis because they did not respond to all the Likert-scaled items. The overall Cronbach’s alpha was .78. This is considered an acceptable reliability level for attitude type instruments (Isaac & Michael, 1995). The final survey instrument used is included as Appendix B.

**Data Analysis**

The data were analyzed using basic descriptive statistics including mean, standard deviation, frequencies, and percentage of respondents. In addition some of the questions on the survey were open ended and coded based on the content of the teacher responses. In addition to their general comments that are reported as a percentage, direct quotes are reported where appropriate. Correlations were drawn where deemed appropriate.

The first research question and subsequent sub-questions, “Do Pennsylvania elementary teachers define science inquiry in a similar way as it is defined in the National Science Education Standards?” The sub-questions include:

a. How familiar are Pennsylvania elementary teachers with the Pennsylvania and National Science Standards, especially in relation to inquiry?

b. Do Pennsylvania elementary teachers recognize the definitions of science inquiry used in the National Science Education Standards (NSES) and Pennsylvania Science and Technology Standards (PSTS) when the definitions are stated literally?
c. Do Pennsylvania elementary teachers recognize the definitions of inquiry used in the National Science Education Standards (NSES) and Pennsylvania Science and Technology Standards (PSTS) when the definitions are stated in context?

These questions were addressed using the survey statements in Chart 1. A Likert-type response scale was provided ranging from 1 to 5 with 1 being Strongly Disagree, 2 Disagree, 3 Undecided, 4 Agree and 5 Strongly Agree or 1 Very Unimportant, 2 Somewhat Unimportant, 3 Unsure, 4 Somewhat Important, 5 Very Important. Agreement or finding statements 9, 10, 15, 16, 18, 19, 21, and 23 important or very important indicates an understanding and acceptance of inquiry as defined by the NSES. If on the other hand, if teachers were more inclined to agree or find statements 20, and 22 important, this could be associated with a more traditional approach.

The open-ended questions in Chart 2 were used to further determine the answers to this research question and the sub-questions related to it. The responses to the short answer questions and scenarios were coded and reported. For question 35, I looked for elements of inquiry as outlined by NRC in *Inquiry and the National Science Standards*. The two scenarios were broken into three sub-questions and were compared for elements on inquiry. In question 36, Mr. Smith’s class is not necessarily an inquiry class even though the description includes the term “hands-on” activities. Often, teachers assume “hands-on” means it is inquiry. Depending on how they responded to what happened previously and what will happen tomorrow determined if they understood the connections with inquiry. For example, if the lesson stops with the “collection of the
Chart 1. Teachers’ Opinions.

From Section 2:

9. Library research could be a part of inquiry based science lessons.

10. Web resources/research could be a part of inquiry based science lessons.

From Section 3 (unidentified as such in survey):

15. Students are engaged in answering a scientifically oriented question.

16. Students should be encouraged to develop their own scientific question.

17. Students are encouraged to find and use scientific evidence through research and/or experimentation to answer the guiding question.

18. Students should formulate explanations from evidence collected through research and/or experiments.

19. Students should be encouraged to connect explanations with prior science knowledge.

20. The majority of the time (70% or more) students should share their findings and justify the explanations only to the teacher in the form of a report or lab sheet.

21. The majority of the time (70% or more) students should share their findings and justify the explanations to a small group within the class.

22. Students should complete a formal lab report using the prescribed scientific method.

23. Students should consider alternative explanations and solutions.
From Section 6:

35. If you were observing a science lesson in the elementary classroom, what specifically would you look for to determine if it was an inquiry-based lesson or not an inquiry based lesson?

36. Scenario #1: Mr. Smith’s class is up, moving around to various lab stations, doing “hands-on” activities, exploring simple machines. At the end of the class, Mr. Smith collects all the worksheets and the students move to the next subject.
   a. Is this an inquiry lesson? Explain your response:
   b. What do you think happened prior to this lesson?
   c. What do you think will happen tomorrow in science class?

37. Scenario #2: As you walk into Mrs. Brown’s class you observe a question on the board, “What do owls eat?” Some students are working on the computer accessing the Internet about owls, others are using the class library to find books on owls and another group are pulling apart owl pellets, categorizing and identifying the various bones.
   a. Is this an inquiry lesson? Explain your response:
   b. What do you think happened prior to this lesson?
   c. What do you think will happen tomorrow in science class?
worksheets” or the explanation of what happens tomorrow is that the worksheets are returned, this is not indicative of inquiry. In question 37, Mrs. Brown’s class appears to be fully engaged in inquiry, but depending on the responses of “What will happen tomorrow?” will determine if teachers fully appreciate the definition of inquiry as outlined by NSES. The teachers’ explanations of whether it was an inquiry lesson or not in section a. carried the primary weight although inquiry ideas might have been found in sections b. or c. and were counted in the scoring.

I designed the scoring rubric to place a greater emphasis on discourse as a key element of inquiry because I believe it is the most overlooked part of inquiry related science activities. The NSES defines inquiry as consisting of: 1. Engaging in a testable question; 2. Priority given to evidence; 3. Predictions, descriptions and explanations given using evidence; 4. Connects evidence and explanation to developing scientific knowledge; and 5. Engages in discourse, justifying the responses with evidence collected. I strongly contend that the final piece, engaging in discourse, is a primary area that is often overlooked or considered a “waste of time” due to the lack of science instructional time. To me, discourse is the most vital component to tie the concept of inquiry learning together for a fuller understanding of the science behind the investigation, hence this is the reason why I applied slightly more weight to the discourse portion when designing the rubric. If the teacher at least responded with items such as “share various concepts they learned; present their findings; compare and contrast findings; share data and justify conclusions,” I felt they were on the right track of including the importance of discourse and gave them the additional point. Again, a limitation to this study was that I could not
go back and individually interview the teachers to see if they truly believed this or not.

The rubrics can be found in Appendices C and D.

To ensure that responses were coded according to each rubric, an additional
person was asked to score a random sampling of 10 percent of the teacher responses. An
explanation of the development of each rubric was provided and, together, we reviewed a
sample set of responses using the pilot results. We agreed on the scoring and the individ-
dual was asked to randomly evaluate 10 percent of the sample population’s responses for
the open-ended question and the two scenarios. A comparison of scores indicated that
the original scores were accurate to the rubric standard enhancing inter-rater reliability.

The second research question, “What is the relationship between self-reported
familiarity with NSES, recognizing NSES definitions of science inquiry literally and
recognizing NSES definitions of science inquiry in context?” is a comparison of the self-
reported familiarity of the standards as outlined in the questions 24, 25, and 26 and their
responses to the literal and context questions (9–23 in Chart 1 and 35-37 in Chart 2)
(Chart 3). In order to correlate the values of the 5-point scale on the elements on inquiry
and the open-ended responses to the 4-point scale used to determine familiarity, it was
necessary to collapse the original scoring as follows.

1. For the elements of inquiry the scale ranged from Strongly Disagree (1);
   Disagree (2); Undecided (3); Agree (4); and Strongly Agree (5). I removed
   the undecided (3) and collapsed responses marked 1 and 2, creating a category
called “Disagree,” and I collapsed responses marked 4 and 5, creating a
category termed “Agree.”
Chart 3. State and National Standards.

From Section 4:

24. How familiar are you with the PA Science and Technology standards?
   1 = Never heard of them
   2 = I know of them, but don’t use them
   3 = Familiar and have referred to them
   4 = Very familiar and refer to them frequently

25. How familiar are you with the PA Environment and Ecology standards?
   1 = Never heard of them
   2 = I know of them, but don’t use them
   3 = Familiar and have referred to them
   4 = Very familiar and refer to them frequently

26. How familiar are you with the National Science Education Standards?
   1 = Never heard of them
   2 = I know of them, but don’t use them
   3 = Familiar and have referred to them
   4 = Very familiar and refer to them frequently
2. For the open ended responses, the terms ranged from: No understanding (1); Very Little understanding (2); Basic Understanding (3); Good understanding (4); Excellent understanding (5). I combined the responses from 1, 2, and 3 and called it “Lacks Understanding” and combined the responses 4 and 5 and called that category “Good Understanding.”

3. For the self-reported familiarity with the Pennsylvania and National Science Standards, I collapsed the four point scale into two points by combining: Never heard of them (1) and I know of them, but don’t use them into (2) into a category called “Lack of Familiarity.” I then put Familiar and have referred to them (3) and Very familiar and refer to them frequently (4) into a category called “Familiar and Uses”

By doing this it put the two areas that identified elements of inquiry literally and in context on a 2-point scale so I could compare them to the self reported familiarity that I also converted to a 2-point scale. Correlations were calculated using Pearson Chi Square and the Phi value was also reported.

The third research question addressed, “To what degree do Pennsylvania elementary teachers agree with accepted principles of effective professional development?” To answer this research question, teachers responded to the statements in Chart 4. The results are reported using basic descriptive statistics including mean, standard deviation, frequencies, and percentage of respondents where appropriate. A Likert-type scale was provided ranging from 1. Strongly Disagree, 2. Disagree, 3. Undecided, 4. Agree and 5. Strongly Agree.
Chart 4. Perceptions Regarding High Quality Professional Development.

High Quality Professional Development (question 32):

a. …focuses on both specific subject matter and the strategies to teach it.

b. …actively engages teachers in the same type of learning activities they are expected to take back into the classroom.

c. …would provide opportunities to connect concepts to the curricular materials the district has.

d. …can occur in one or two day in-service programs.

e. …creates opportunities for teachers to serve in leadership roles and share their expertise with colleagues.

f. …includes support from administrators as teachers attempt changes in the classroom.

g. …includes flex days or trade days that allow you time to work individually in preparing your classroom.

h. …includes “menu” opportunities for 1, 2 or 4 hour sessions on a variety of topics.

i. …is a long-term process.

j. …provides opportunities for self-reflection.

k. …provides opportunities for collaborative work with colleagues.

l. …provides structures and strategies that allow teachers to learn from their daily teaching practice.
Agreement with statements a, b, c, e, f, i, j, k and l indicates understanding of high quality professional development models. Three additional statements were added as distracters including statements that suggest professional development can be accomplished in a short period of time and should include “flex time” to work on classroom preparation. These statements were added in consultation with the doctoral committee, to see how many would choose them given the category of high quality professional development.

The final research question was, “To what degree are Pennsylvania elementary teachers willing to participate in professional development activities that match accepted principles of effective professional development when the professional development is focused on science inquiry?” To address this question, teachers responded to specific statements. The results are reported using basic descriptive statistics including mean, standard deviation, frequencies and percentage of responders where appropriate. In addition, this section allowed teachers to add additional comments which were coded and reported using descriptive statistics and direct quotes where deemed appropriate.

In responding to the first section, teachers could only choose yes or no, so the opportunity to add comments was included. In the second section, two statements highlighting short time periods for professional development and the opportunity to work individually in the classroom were included to see how many would choose these categories. The third section was a comparison of two sets of statements to compare what a teacher would like to see happen versus the reality of what is happening in relation to working with colleagues on professional development (Chart 5).
Chart 5. Perceptions Regarding Participation in Professional Development.

From Section 5: Yes or no responses with an opportunity to add comments.

27. Would you be willing to attend a daylong summer in-service on incorporating science inquiry in your science lessons? Yes No

28. Would you be willing to attend evening workshops during the school year on incorporating inquiry in your science lessons? Yes No

29. Would you be willing to attend a weeklong residential program focusing on science topics during the summer months? Yes No

30. Would you be willing to meet during the school year (eight or more times) with same grade level individuals to discuss science curriculum and ideas?
   Yes No
   If yes
   a. Would you be willing to meet after school hours? Y N
   b. Would you be willing to meet before school hours? Y N
   c. Would you be willing to meet during school hours? Y N
   d. Would you be willing to meet during in-service days? Y N
   Why or why not: __________________________________________

31. Please feel free to add any comments or thoughts you may have about availability for professional development opportunities:

33. I would be willing to participate in professional development related to science…
   a. … to increase my science knowledge
   b. … to improve my science teaching techniques
   c. … that uses learning activities similar to those that I would be expected to use with my students.
   d. … that focuses on the curriculum in my district
   e. … as long as it is a day-long in-service, once or twice a year
   f. … to develop leadership skills in science education
   g. … in which colleagues who have expertise serve as workshop leaders
   h. … if my principal also participated in the workshop activities
   i. … if it meant having time in my room to work individually
   j. … as long as I can choose from a variety of science topics
   k. … over a long period of time
   l. … if I was able to do self-reflection of my work
   m. … if I was able to work collaboratively with colleagues
In addition, the responses between questions 11, 12, 13 and 14 (What a teacher would like to have happen) were compared to the responses to questions 34 a–d (the self-reported reality of what is occurring in the schools) (Chart 6).

Some general information (section 1) was collected to identify teachers who responded and to identify them by gender, years of experience, grade level, number of minutes per week science is taught and specific certification areas. Also, the use of kit based programs and professional development participation were queried. This information is reported using basic descriptive statistics including frequencies and percentage of respondents. The questions addressed in this part are shown in Chart 7.

Chart 6. Comparison of Selected Questions.

11. I would like to have time during the regular school week to work with my colleagues on science curriculum and teaching.

12. I would like to regularly share ideas and materials related to science teaching with my colleagues.

13. I would like to regularly observe other teachers teaching science as part of sharing and improving instructional strategies.

14. I want to contribute actively to making decisions about the science curriculum.

34a. Meet with colleagues during the regular school week to work on science curriculum and teaching strategies

34b. Share ideas and materials related to science teaching with my colleagues

34c. Observe other teachers teaching science as part of improving strategies

34d. Actively contribute to making decisions about the science curriculum

1. Gender  ______ Male _______ Female

2. How many years have you been teaching (at the end of this year)?
    _______ years

3. What grade level(s) are you teaching this year?
    ______

4. Do you teach in a self-contained classroom?
   ____ Yes   ____ No
   If no: List the area(s) you specialize in teaching: ________________

5. How many minutes per week (on the average) are used for science?
    ___________ minutes

6. What is (are) your certification area(s)? (Check all that apply)
   ____ Elementary certification
   ____ Early Childhood
   ____ Other
   If other, please specify) ______________________________________

7. Are you using any kit-based program currently in your science curriculum?
   ____ Yes   ____ No
   If yes, specify the kit(s):
   ____ FOSS
   ____ STS
   ____ other (specify)_________________________________________

8. In the past three years, have you attended any professional development
   programs related to science?
   ____ Yes   ____ No
   If yes, please check the type(s) that apply:
   ____ university sponsored course
   ____ IU offering
   ____ district in-service
   ____ other (specify: __________________________________________
Limitations to the Study

Though a survey was a useful tool in capturing responses from a large number of elementary teachers, choosing a survey as the data collection strategy also has some shortcomings in terms of delving deeply into teachers’ conceptual understanding of concepts like science inquiry. Since I used an anonymous survey instrument, it did not allow me to go back and review the results or responses with individual teachers in order to clarify answers and ensure there was no confusion. There was no opportunity to probe for additional clarification or for deeper understanding. This also meant I did not have the opportunity to observe specific teachers who had interesting responses to the questions. This would have been very beneficial and would have added to the study. In the future, if I were to re-use this instrument, I would request additional permission to identify the individuals so I could contact them for an interview and or observation. This would be a self-selected group since they would have the option of remaining anonymous, which can also be seen as a limitation.

Some issues that came up in reviewing the surveys were trying to determine if the teachers truly understood and utilized discourse in their classes or if they just chose words that appeared to make sense. Also, it was difficult to determine if the respondents had a good understanding of the various parts of inquiry learning and their views on inquiry teaching. In addition, had I utilized a method that would have allowed me to identify the individuals, I might have been able to clear up some of the discrepancies with the amount of time teaching science each week.
Chapter 4

FINDINGS

Introduction

This chapter summarized the findings of elementary school teachers’ understandings regarding teaching science as inquiry. It begins with respondents’ demographic profile and subsequently addresses four over-arching research questions, in addition to the three sub-questions which were subcomponents of the first overarching question.

Demographic Profile of Respondents

A total of 728 surveys were distributed during the second week of May 2005. The data were collected at the time of year when most teachers were completing their end of year activities with students, and this probably influenced the response rate. The final surveys came in by June 10, 2005. Of the 238 surveys returned, 228 were deemed usable based on the completeness of the information provided (Table 2, p. 71). This represents a 31 percent response rate. The data were “cleaned” by the researchers using basic frequencies to access whether there were data entry errors or responses provided to closed ended items that did not fit the viable response options.

Male respondents totaled 32 (14%) and 196 (86%) were female. The vast majority (87%) taught in self-contained classrooms, but 30 (13%) taught in specialized classrooms with 23 explaining or describing their area of specialty. Twelve individuals (5%) did not teach science, but did respond to most of the remaining questions based on
prior experience and are included in the analysis. The respondents taught for an average of 17.29 years, but the range was from a low of 1 to a high of 40 years, reflecting a wide distribution of teaching experience. The mean for the number of minutes per week of science instruction was 119 minutes (about 2 hours), but ranged from 0 to 600 minutes (10 hours) per week. It should be noted that four teachers specified that they specialized in teaching science, and one of the schools included had a science magnet program which could explain the 600 minutes per week response (Table 3).

I became more interested in teacher use of resources, specifically, kit-based science programs after I realized that one-half of the respondents, 113 (49.6%), indicated they were using a kit-based program. The Science It’s Elementary (SIE) program being promoted in Pennsylvania is based on the use of the kits, and more research has recently been published about the professional development and the use of kits in the classroom. Again, a limitation to the study was the fact that I could not go back and interview those using the kits to see if they faced similar issues as the ones identified in Banilower’s studies (2007, 2008). Of those indicating using kits, 88 of the 113 (77.9%) indicated they were using Foss kits and an additional 13 of the 113 (11.5%) reported using STS kits. Additional resources reportedly used by at least five respondents included: “scholastic science” and “Carroll County, Maryland curriculum.”

I was also interested in whether or not the teachers had participated in any science related professional development activity in the past three years. One hundred thirty-two individuals (57.5%) indicated they had participated in some form of science related professional development within the last three years, while 98 (42.5%) had not. Thirteen
Table 3. Profile of Respondents.

<table>
<thead>
<tr>
<th>Variables</th>
<th>n</th>
<th>Mean</th>
<th>SD</th>
<th>25th</th>
<th>50th</th>
<th>75th</th>
<th>Range</th>
<th>Low</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Years teaching</td>
<td>228</td>
<td>17.29</td>
<td>11.05</td>
<td>7</td>
<td>17</td>
<td>28</td>
<td>1</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>Minutes/week</td>
<td>223</td>
<td>119.00</td>
<td>73.32</td>
<td>75</td>
<td>115</td>
<td>150</td>
<td>0</td>
<td>600</td>
<td></td>
</tr>
</tbody>
</table>

Of those specializing, 23 of the 30 specified what they specialize in: 4 teach only science, 9 teach a combination of subjects including science and 12 teach a combination of subjects, but not science. It is interesting to note that most of these respondents still answered the questions.
of the 132 who participated (9.9%) indicated that the professional development was
through university offerings, 24 (18.1%) individuals indicated the professional
development was offered by the local Intermediate Unit and 107 (81.1%) indicated they
had some professional development related to science offered by their own district.
Individuals were allowed to indicate multiple types of professional development activity.

Research Questions

Four overarching questions were addressed in the study. The first question was:
Do Pennsylvania elementary teachers define science inquiry in a similar way as it is
defined in the National Science Education Standards?” To more systematically address
the main question relating to teachers’ familiarity with NSES three sub-questions were
also addressed. The first sub-question deals with the National and Pennsylvania standards
documents; the second sub-question takes the elements of inquiry and breaks them into
literal statements; the third sub-question deals with the elements of inquiry stated in
context to see if teachers could identify them in this way.

Identification of Inquiry Components

To begin the data analysis for the first overarching question, an exploratory factor
analysis was used to identify which items, if any, loaded onto teaching science as inquiry
subscales. The results from principle components factor analysis (PCA) are presented in
Table 4. Three factors emerged using the general guidelines offered by Afifi, Clark and
May (2004). Results from the PCA indicated these factors were identified:

1. Identifying principles of inquiry (6 items, Cronbach alpha = .85)
Table 4. Principle Components Factor Analysis Results for Elements of Inquiry.

<table>
<thead>
<tr>
<th>Scale name, reliability and item loading for components of inquiry scale</th>
<th>Factor Rotated Loading</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. Identified principles of inquiry (n=228)</strong></td>
<td></td>
</tr>
<tr>
<td>Cronbach alpha .85</td>
<td></td>
</tr>
<tr>
<td>Mean 4.35</td>
<td></td>
</tr>
<tr>
<td>S.D. .56</td>
<td></td>
</tr>
<tr>
<td>Students are engaged in answering a scientifically oriented question.</td>
<td>.73</td>
</tr>
<tr>
<td>Students should be encouraged to develop their own scientific question.</td>
<td>.74</td>
</tr>
<tr>
<td>Students are encouraged to find and use scientific evidence through research and/or experimentation to answer the guiding question.</td>
<td>.82</td>
</tr>
<tr>
<td>Students should formulate explanations from evidence collected through research and/or experiments.</td>
<td>.81</td>
</tr>
<tr>
<td>Students should be encouraged to connect explanations with prior science knowledge.</td>
<td>.79</td>
</tr>
<tr>
<td>Students should consider alternative explanations and solutions.</td>
<td>.58</td>
</tr>
<tr>
<td><strong>B. Information search (n=222)</strong></td>
<td></td>
</tr>
<tr>
<td>Cronbach alpha .84</td>
<td></td>
</tr>
<tr>
<td>Mean 4.14</td>
<td></td>
</tr>
<tr>
<td>S.D. .58</td>
<td></td>
</tr>
<tr>
<td>Library research could be a part of inquiry based science lessons</td>
<td>.93</td>
</tr>
<tr>
<td>Web resources/research could be a part of inquiry based science lessons</td>
<td>.90</td>
</tr>
<tr>
<td><strong>C. Reporting information (n=222)</strong></td>
<td></td>
</tr>
<tr>
<td>Cronbach alpha .54</td>
<td></td>
</tr>
<tr>
<td>Mean 3.1</td>
<td></td>
</tr>
<tr>
<td>S.D. .76</td>
<td></td>
</tr>
<tr>
<td>The majority of the time (70% or more) students should share their findings and justify the explanations only to the teacher in the form of a report or lab sheet.</td>
<td>.79</td>
</tr>
<tr>
<td>The majority of the time (70% or more) students should share their findings and justify the explanations to a small group within the class.</td>
<td>.55</td>
</tr>
<tr>
<td>Students should complete a formal lab report using the prescribed scientific method.</td>
<td>.73</td>
</tr>
<tr>
<td>Response scale for each item was 1= strongly disagree 2= disagree 3= undecided 4= agree 5= strongly agree</td>
<td></td>
</tr>
<tr>
<td>Kaiser-Meyer-Olkin Measures of Sampling Adequacy = .81 (.7 or higher is desired per Afifi, Clark &amp; May, 2004))</td>
<td></td>
</tr>
<tr>
<td>Bartlett’s Test of Sphericity App. Chi-Square = 806.38</td>
<td></td>
</tr>
<tr>
<td>Df = 55; Sig = &lt;.001 (&lt;.05 is desired per Afifi, Clark and May 2004)</td>
<td></td>
</tr>
</tbody>
</table>
2. Information search (2 items, Cronbach alpha = .84)

3. Reporting information (3 items, Cronbach alpha = .54)

The reliability of .54 for the Reporting Information scale is low compared to the commonly accepted standard of .7 (Isaac & Michael, 1995).

**Familiarity with Pennsylvania and National Science Standards**

Using a Likert-type scale, teachers were asked to rate their familiarity and usage of state and national science education standards. This information was used to address the following study question: How familiar are Pennsylvania elementary teachers with the Pennsylvania and National Science Education standards, especially in relation to inquiry?

In direct response to a question asking the teachers to indicate their familiarity with the National Science Education Standards (NSES), the respondents were generally not that familiar with the NSES (Table 5) with almost 60 percent indicating either “never heard of them” or “heard of them, but not referring to them.” In addition, I was interested in the teachers’ familiarity with the Pennsylvania Standards related to science. There are two separate sets of standards in Pennsylvania, namely the Pennsylvania Science and Technology (PS&T) and Pennsylvania Environment and Ecology Standards (PE&E). Between the two sets of state standards, teachers were much more familiar with the science and technology standards indicating “familiar and refer to them” and “very familiar and refer to them frequently” (73.3%) than they were with the environment and ecology standards (44.7%). These results indicate the need for more professional development, in introducing and using the standards, especially the Pennsylvania
Table 5. Self-Reported Familiarity with the Pennsylvania and National Science Standards.

<table>
<thead>
<tr>
<th>Item</th>
<th>N</th>
<th>Never heard</th>
<th>Know, but do not use</th>
<th>Familiar and refer</th>
<th>Very familiar refer to often</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pennsylvania Science and Technology Standards</td>
<td>225</td>
<td>4.4</td>
<td>22.2</td>
<td>60.4</td>
<td>12.9</td>
<td>2.82</td>
<td>.71</td>
</tr>
<tr>
<td>Pennsylvania Environment and Ecology Standards</td>
<td>226</td>
<td>21.2</td>
<td>34.1</td>
<td>35.4</td>
<td>9.3</td>
<td>2.33</td>
<td>.91</td>
</tr>
<tr>
<td>National Science Education Standards</td>
<td>226</td>
<td>9.7</td>
<td>49.6</td>
<td>37.6</td>
<td>3.1</td>
<td>2.34</td>
<td>.70</td>
</tr>
</tbody>
</table>
Environment and Ecology standards, since Pennsylvania elementary teachers are not that familiar with the standards that are “considered law and must be taught” (Vathis, Personal Communication, Sept 2005).

**Understanding the Definition of Science Inquiry**

Familiarity with the standards was addressed in the first sub-question, but to further break it down, I wanted to see if teachers would identify the elements of inquiry, an important component of the standards, even if they said they were not that familiar with the standards. In other words, if they saw elements of inquiry literally stated, would they identify the elements? That information was used to address the following study question: Do Pennsylvania elementary science teachers recognize the definitions of science inquiry used in the NSES and the Pennsylvania Science and Technology (PS&T) when the definitions are stated literally?

Table 6 indicates the elements of inquiry stated literally. Agreement (composite of agree and strongly agree) with most of the statements indicates that the teachers recognize the individual elements of inquiry. Over 90 percent of the respondents agreed or strongly agreed with the following elements: Students are engaged in answering a scientifically oriented question (93%); Students should be encouraged to develop their own scientific question (90%); Students are encouraged to find and use scientific evidence through research and/or experimentation to answer the guiding question (92%); Students should formulate explanations from evidence collected through research and/or experiments (92%); and Students should be encouraged to connect explanations with
<table>
<thead>
<tr>
<th>Item:</th>
<th>N</th>
<th>SD</th>
<th>D</th>
<th>U</th>
<th>A</th>
<th>SA</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Library research could be a part of inquiry based science lessons</td>
<td>228</td>
<td>--</td>
<td>2</td>
<td>11</td>
<td>62</td>
<td>25</td>
<td>4.09</td>
<td>.66</td>
</tr>
<tr>
<td>Web resources/research could be a part of inquiry based science lesson</td>
<td>228</td>
<td>--</td>
<td>1</td>
<td>7</td>
<td>63</td>
<td>29</td>
<td>4.20</td>
<td>.59</td>
</tr>
<tr>
<td>Students are engaged in answering a scientifically oriented question</td>
<td>225</td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>48</td>
<td>45</td>
<td>4.38</td>
<td>.68</td>
</tr>
<tr>
<td>Students should be encouraged to develop their own scientific question</td>
<td>225</td>
<td>1</td>
<td>2</td>
<td>7</td>
<td>52</td>
<td>38</td>
<td>4.24</td>
<td>.75</td>
</tr>
<tr>
<td>Students are encouraged to find and use scientific evidence through research and/or experimentation to answer the guiding question</td>
<td>224</td>
<td>1</td>
<td>1</td>
<td>6</td>
<td>40</td>
<td>52</td>
<td>4.42</td>
<td>.71</td>
</tr>
<tr>
<td>Students should formulate explanations from evidence collected through research and/or experiments.</td>
<td>223</td>
<td>1</td>
<td>1</td>
<td>6</td>
<td>36</td>
<td>56</td>
<td>4.44</td>
<td>.74</td>
</tr>
<tr>
<td>Students should be encouraged to connect explanations with prior science knowledge</td>
<td>225</td>
<td>1</td>
<td>--</td>
<td>3</td>
<td>30</td>
<td>66</td>
<td>4.60</td>
<td>.66</td>
</tr>
<tr>
<td>The majority of the time (70% or more) students should share their findings and justify the explanations only to the teacher in the form of a report or lab sheet.</td>
<td>224</td>
<td>21</td>
<td>39</td>
<td>19</td>
<td>17</td>
<td>4</td>
<td>2.43</td>
<td>1.12</td>
</tr>
<tr>
<td>The majority of the time (70% or more) students should share their findings and justify the explanations to a small group within the class.</td>
<td>224</td>
<td>3</td>
<td>7</td>
<td>9</td>
<td>60</td>
<td>21</td>
<td>3.89</td>
<td>.91</td>
</tr>
<tr>
<td>Students should complete a formal lab report using the prescribed scientific method.</td>
<td>222</td>
<td>12</td>
<td>21</td>
<td>31</td>
<td>29</td>
<td>7</td>
<td>2.98</td>
<td>1.13</td>
</tr>
<tr>
<td>Students should consider alternative explanations and solutions.</td>
<td>223</td>
<td>2</td>
<td>4</td>
<td>10</td>
<td>56</td>
<td>28</td>
<td>4.02</td>
<td>.86</td>
</tr>
</tbody>
</table>

Response scale: 1 = Strongly Disagree; 2 = Disagree; 3 = Undecided; 4 = Agree; 5 = Strongly Agree
prior science knowledge (96%). Over 80 percent of the respondents agreed with the following two statements: The majority of the time (70% or more) students should share their findings and justify the explanations to a small group within the class (81%); Students should consider alternative explanations and solutions (84%). Only 21 percent of the teachers agreed or strongly agreed to the statement: The majority (70% or more) of the time students should share their findings and justify the explanations only to the teacher in the form of a report or lab sheet. Sixty percent of the teachers disagreed or strongly disagreed with this statement and 19 percent remained undecided.

Only 36 percent agreed or strongly agreed to the statement: Students should complete a formal lab report using the prescribed scientific method. Of the remaining responses, 33 percent disagreed or strongly disagreed and 31 percent were undecided.

Extending the definitions of inquiry further, I was interested in assessing if the teachers only saw inquiry as a “hands-on” activity, and thus asked if web resources and library research could be part of inquiry based science lessons. In a literal sense, the results were 87 percent of the respondents agreed or strongly agreed that library research could be a part of inquiry based science lessons and 92 percent agreed or strongly agreed that Web resources/research could be a part of inquiry based science lessons.

Overall, this indicates a good view of the elements of inquiry when they are literally spelled out even among the teachers who indicated they were not familiar with the national and state standards, but do they know what it looks like in action and are they implementing it?
Defining Inquiry within Context

In this final sub-question, again reviewing the elements of inquiry, but this time in context, I was interested in whether the teachers could identify the essential parts of inquiry when reading a situation within context. This involved open ended questions that were hand-scored using a rubric. For this question, respondents were asked to respond to open-ended questions reflecting three different situations. This information was used to address the following study question: Do Pennsylvania elementary teachers recognize the definitions of inquiry used in the National Science Education Standards (NSES) and Pennsylvania Science and Technology Standards (PSTS) when the definitions are stated in context?

The first open-ended question was: “If you were observing a science lesson in the elementary classroom, what specifically would you look for to determine if it was an inquiry-based lesson or not an inquiry based lesson?” Seventy-two percent of the teachers responded, and their answers were coded using a rubric I designed (Appendix C). To check for inter-rater reliability of the scoring process, another researcher in a different discipline was trained using the rubric. She scored randomly selected responses and the scoring was compared to the original score assigned.

For the two scenarios, teachers were given specific details and asked three separate questions: a. Is this an inquiry lesson? Explain your response. b. What do you think happened prior to this lesson? c. What do you think will happen tomorrow in science class? A second scoring rubric was developed to address each component and can be found in Appendix D. Again, to check for inter-rater reliability, a researcher from
another department was trained using the scoring process and she scored randomly selected responses, comparing the scores to the original scores.

It is interesting to note that the view of inquiry increased as the questions progressed (Table 7). In the first open-ended statement, only 26 percent had a good understanding of inquiry, and no one scored at the excellent level. As they moved through the scenarios, 71 percent were able to justify their responses with the elements of inquiry, scoring a good to excellent understanding and by the last scenario 74 percent achieved a good to excellent understanding. This could be because the last scenario was more comprehensive of an inquiry based lesson and was recognized as such by most of the teachers. Over 90 percent of the teachers identified the second scenario as an inquiry based lesson, compared to only 28 percent who felt the first scenario represented an inquiry lesson.

A further review of the responses to the three open-ended questions revealed that the term “hands-on” was used with decreasing frequency in justifying the answers. In the first open-ended question which asked the respondents to explain what they would look for in an inquiry lesson, over 28 percent specifically used the term “hands-on” with an additional 17 percent of respondents specifying terms such as “actively engaged,” “student involvement,” and “activities.” In the first scenario, only 14 percent used the term “hands-on” and an additional 7 percent used the other three terms. By the last scenario, the “hands-on” response was only used 3 percent of the time and other three terms were used less than 1 percent of the time. It should be noted that, in Scenario 1, the term “hands-on” was used and this may account for the identification of the term.
Table 7. Teacher Interpretations to Open-Ended Questions and Scenarios.

<table>
<thead>
<tr>
<th>Item:</th>
<th>N</th>
<th>No Understanding %</th>
<th>Very Little Understanding %</th>
<th>Basic Understanding %</th>
<th>Good Understanding %</th>
<th>Excellent Understanding %</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open-ended question: If you were observing a science lesson in the elementary classroom, what specifically would you look for to determine if it was an inquiry-based lesson or not an inquiry based lesson?</td>
<td>164</td>
<td>22</td>
<td>38</td>
<td>14</td>
<td>26</td>
<td>0</td>
<td>2.43</td>
<td>1.11</td>
</tr>
<tr>
<td>Scenario #1: Mr. Smith’s class is up, moving around to various lab stations, doing “hands–on” activities, exploring simple machines. At the end of the class, Mr. Smith collects all the worksheets and the students move to the next subject.</td>
<td>170</td>
<td>2</td>
<td>5</td>
<td>22</td>
<td>70</td>
<td>1</td>
<td>3.63</td>
<td>0.69</td>
</tr>
<tr>
<td>a. Is this an inquiry lesson? Explain your response:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. What do you think happened prior to this lesson?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. What do you think will happen tomorrow in science class?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scenario #2: As you walk into Mrs. Brown’s class you observe a question on the board, “What do owls eat?” Some students are working on the computer accessing the Internet about owls, others are using the class library to find books on owls and another group is pulling apart owl pellets, categorizing and identifying the various bones.</td>
<td>169</td>
<td>2</td>
<td>3</td>
<td>21</td>
<td>72</td>
<td>2</td>
<td>3.69</td>
<td>0.66</td>
</tr>
<tr>
<td>a. Is this an inquiry lesson? Explain your response:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. What do you think happened prior to this lesson?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. What do you think will happen tomorrow in science class?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The last part of inquiry, sharing and justifying results, is a key element that I felt was often overlooked by teachers. In the first open-ended question asking teachers what they would look for to determine if the lesson was inquiry based, only 18 percent mentioned discussion or sharing of results. Teachers responses to the scenarios provided better results with 69 percent and 66 percent, respectively, identifying the importance of discussing/sharing results, although, no one specified the concept of defending responses with evidence gathered.

Relationship between Familiarity and Defining Science Inquiry

The second overarching research question to be addressed was: What is the relationship between self-reported familiarity with NSES, recognizing NSES definitions of science inquiry literally and recognizing NSES definitions of science inquiry in context?

Using SPSS Crosstabs, I compared the self–reported familiarity with the National Science Education Standards (a nominal variable) and the literal definitions of inquiry and found that there was a low correlation (Cramer’s variable=.2) A Cramer’s variable of .2 indicates little relationship between self reported familiarity and their definition of inquiry. Further evidence regarding the lack of a pattern between understanding science as inquiry and the elements of inquiry is found in the following. Even those lacking understanding of the NSES had a high degree of agreement with the elements of inquiry, with over 90 percent of the teachers agreeing with eight of the nine elements identified (Table 8). For the additional element, even though the respondents indicated a lack of understanding of the standards, they agreed with this element of inquiry at a fairly high
Table 8. Teacher Reported Familiarity with National Science Education Standards Correlated with the Elements of Inquiry Both Literal and in Context.

<table>
<thead>
<tr>
<th>National Science Education Standards (Question 26)</th>
<th>Lack of Understanding</th>
<th>Familiar and Uses</th>
<th>Chi-Square</th>
<th>Phi Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Library research</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Disagree</td>
<td>3.3</td>
<td>1.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agree</td>
<td>96.7</td>
<td>98.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Web resources</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Disagree</td>
<td>1.6</td>
<td>0.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agree</td>
<td>98.4</td>
<td>100.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Students engaged in question</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Disagree</td>
<td>2.4</td>
<td>0.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agree</td>
<td>97.6</td>
<td>100.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Student develop their own question</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Disagree</td>
<td>5.0</td>
<td>1.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agree</td>
<td>95.0</td>
<td>98.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Student finds and uses evidence</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Disagree</td>
<td>2.5</td>
<td>0.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agree</td>
<td>97.5</td>
<td>100.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Formulates explanation based on evidence</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Disagree</td>
<td>2.5</td>
<td>2.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agree</td>
<td>97.5</td>
<td>97.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Connect explanation with prior knowledge</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Disagree</td>
<td>2.4</td>
<td>0.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agree</td>
<td>97.6</td>
<td>100.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Share and justify explanations in small groups</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Disagree</td>
<td>14.4</td>
<td>6.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agree</td>
<td>85.6</td>
<td>94.0</td>
<td>3.513</td>
<td>.132</td>
</tr>
</tbody>
</table>
Table 8. Continued.

<table>
<thead>
<tr>
<th>National Science Education Standards (Question 26)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elements of inquiry …</td>
</tr>
<tr>
<td>-----------------------</td>
</tr>
<tr>
<td>Consider alternative explanations and solutions</td>
</tr>
<tr>
<td>Disagree</td>
</tr>
<tr>
<td>Agree</td>
</tr>
<tr>
<td>Open ended: What do you look for to determine if it is an inquiry lesson?</td>
</tr>
<tr>
<td>Lacks understanding</td>
</tr>
<tr>
<td>Good understanding</td>
</tr>
<tr>
<td>Scenario 1: Simple machines stations</td>
</tr>
<tr>
<td>Lacks understanding</td>
</tr>
<tr>
<td>Good understanding</td>
</tr>
<tr>
<td>Scenario 2: Owl study</td>
</tr>
<tr>
<td>Lacks understanding</td>
</tr>
<tr>
<td>Good understanding</td>
</tr>
</tbody>
</table>
level (85.6% agreeing). For those who indicated that they used the standards, there was a stronger agreement with the nine literal inquiry statements ranging from 94 percent to 100 percent. In regard to the contextual statements (open-ended responses), the correlation was not as strong, but was still evident in the two scenarios. Those indicating a lack of familiarity with the NSES still scored a relatively high level with 67.6 percent and 74.5 percent; whereas, those indicating familiarity agreed at a slightly higher level, 74.6 percent and 72.7 percent, respectively. The first open ended question asked the teachers to describe what they would look for to determine if a class was participating in an inquiry-based lesson. Somewhat surprising was 17.9 percent of respondents who lack familiarity with the NSES, had a good understanding of inquiry and 36.8 percent of those that were familiar with the standards had a good understanding of inquiry.

I went back and checked the results for the other two sets of Pennsylvania standards and found similar results, including low results for the initial open-ended question, so in general there was no significant difference or pattern between those who said they lacked understanding and those who said they were familiar with the standards in terms of their literal recognition of the elements of inquiry or in their recognition of the elements of inquiry in context.

Basic Principles of Professional Development

The third overarching research question to be addressed was: To what degree do Pennsylvania elementary teachers agree with accepted principles of effective professional development?
For the most part, the large majority of teachers (over 78%) agreed or strongly agreed with the accepted principles of professional development (Table 9), but they also agreed or strongly agreed with contradictory statements that were included as distracters. Although 89 percent agreed that high quality professional development is a long term process, 76 percent also indicated it could be one or two day in-service programs. This may indicate the pressure of a lack of time during a school year and the need to accomplish a lot in a small amount of time or their frustration in not understanding the need for more professional development, especially if they were not included in the planning process and do not “buy into” the need for the professional development.

In relation to “menu” opportunities for 1, 2, or 4 hour session on a variety of topics, 78 percent indicated that this was indicative of high quality professional development. Although this is a common occurrence in many school districts, it only offers a “taste” of what could be occurring in classrooms. Teachers that are highly motivated may take the opportunities as introductions of new approaches and information, and may develop their own action research project in their classrooms, but this unfortunately will be the rare exception, unless strongly encouraged or even mandated by the school or district. For the most part, teachers will “choose” areas where they feel a comfort level and will not be exposed to “new” ideas.

The final distracter included “flex days or trade days that allow you to work individually in preparing your classroom” of which 89 percent agreed or strongly agreed. Although this is a luxury, it does not represent high quality professional development, but rather reflects the time constraint many teachers feel in trying to accomplish all the
Table 9. Recognizing Elements of High Quality Professional Development.

<table>
<thead>
<tr>
<th>High Quality Professional Development…</th>
<th>N*</th>
<th>SD</th>
<th>D</th>
<th>U</th>
<th>A</th>
<th>SA</th>
</tr>
</thead>
<tbody>
<tr>
<td>focuses on both specific subject matter and the strategies to teach it.</td>
<td>225</td>
<td>--</td>
<td>--</td>
<td>1</td>
<td>21</td>
<td>67</td>
</tr>
<tr>
<td>actively engages teachers in the same type of learning activities they are expected to take back into the classroom.</td>
<td>226</td>
<td>--</td>
<td>2</td>
<td>3</td>
<td>31</td>
<td>64</td>
</tr>
<tr>
<td>would provide opportunities to connect concepts to the curricular materials the district has.</td>
<td>226</td>
<td>--</td>
<td>1</td>
<td>3</td>
<td>33</td>
<td>63</td>
</tr>
<tr>
<td>can occur in one or two day in-service programs.</td>
<td>226</td>
<td>2</td>
<td>8</td>
<td>14</td>
<td>42</td>
<td>34</td>
</tr>
<tr>
<td>creates opportunities for teachers to serve in leadership roles and share their expertise with colleagues.</td>
<td>226</td>
<td>--</td>
<td>3</td>
<td>19</td>
<td>54</td>
<td>24</td>
</tr>
<tr>
<td>includes support from administrators as teachers attempt changes in the classroom.</td>
<td>224</td>
<td>6</td>
<td>1</td>
<td>6</td>
<td>38</td>
<td>49</td>
</tr>
<tr>
<td>includes flex days or trade days that allow you time to work individually in preparing your classroom.</td>
<td>226</td>
<td>1</td>
<td>--</td>
<td>10</td>
<td>23</td>
<td>66</td>
</tr>
<tr>
<td>includes “menu” opportunities for 1, 2 or 4 hour sessions on a variety of topics.</td>
<td>226</td>
<td>--</td>
<td>2</td>
<td>20</td>
<td>48</td>
<td>30</td>
</tr>
<tr>
<td>is a long-term process.</td>
<td>226</td>
<td>1</td>
<td>2</td>
<td>8</td>
<td>41</td>
<td>48</td>
</tr>
<tr>
<td>provides opportunities for self-reflection.</td>
<td>225</td>
<td>1</td>
<td>3</td>
<td>9</td>
<td>56</td>
<td>31</td>
</tr>
<tr>
<td>provides opportunities for collaborative work with colleagues.</td>
<td>226</td>
<td>--</td>
<td>1</td>
<td>4</td>
<td>49</td>
<td>46</td>
</tr>
<tr>
<td>provides structures and strategies that allow teachers to learn from their daily teaching practice.</td>
<td>225</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>48</td>
<td>43</td>
</tr>
</tbody>
</table>
paperwork required in the current classroom climate in addition to preparing engaging lessons for the students.

**Desire to Participate in Professional Development**

The fourth overall research question to be addressed was: To what degree are Pennsylvania elementary teachers willing to participate in professional development activities that match accepted principles of effective professional development when the professional development is focused on science inquiry?

Table 10 indicates respondents’ willingness to participate in professional development specifically related to science inquiry. Thirteen items were included, but three items, although matching accepted principles of professional development, did not receive as much agreement as the other principles. In particular, only 56 percent and 57 percent, respectively, agreed or strongly agreed with items, “to develop leadership skills in science education” and “if I was able to do self-reflection of my work.” Only 33 percent agreed or strongly agreed with the concept of the principal being involved in the workshop activities.

To the statement offering time to work alone in his/her classroom, 79 percent agreed or strongly agreed. Again, a matter of time-constraint remains an issue and teachers are always looking for more time to do what they need to do to catch up – this does not mean that individual time spent in one’s own room would necessarily be focused on science. Finally, only 47 percent agreed or strongly agreed to the concept that professional development related to science inquiry should occur over a long period of time. Earlier, in relation to professional development in general, 89 percent agreed that it
Table 10. Respondents’ Willingness to Participate in Professional Development Related to Science Inquiry.

<table>
<thead>
<tr>
<th>I would be willing to participate in professional development related to science…</th>
<th>N</th>
<th>SD</th>
<th>D</th>
<th>U</th>
<th>A</th>
<th>SA</th>
<th>Valid Percent of Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>..to increase my science knowledge</td>
<td>223</td>
<td>1</td>
<td>3</td>
<td>7</td>
<td>53</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td>..to improve my science teaching techniques.</td>
<td>223</td>
<td>---</td>
<td>---</td>
<td>4</td>
<td>44</td>
<td>52</td>
<td></td>
</tr>
<tr>
<td>..that uses learning activities similar to those that I would be expected to use with my students.</td>
<td>223</td>
<td>1</td>
<td>---</td>
<td>3</td>
<td>38</td>
<td>58</td>
<td></td>
</tr>
<tr>
<td>..that focuses on the curriculum in my district.</td>
<td>221</td>
<td>---</td>
<td>---</td>
<td>4</td>
<td>47</td>
<td>49</td>
<td></td>
</tr>
<tr>
<td>..as long as it is a day-long in-service, once or twice a year.</td>
<td>221</td>
<td>2</td>
<td>4</td>
<td>22</td>
<td>47</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>..to develop leadership skills in science education.</td>
<td>222</td>
<td>1</td>
<td>10</td>
<td>33</td>
<td>45</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>..in which colleagues who have expertise serve as workshop leaders.</td>
<td>223</td>
<td>1</td>
<td>5</td>
<td>18</td>
<td>54</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>..if my principal also participated in the workshop activities.</td>
<td>222</td>
<td>4</td>
<td>16</td>
<td>47</td>
<td>23</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>..if it meant having time in my room to work individually.</td>
<td>222</td>
<td>1</td>
<td>4</td>
<td>16</td>
<td>40</td>
<td>39</td>
<td></td>
</tr>
<tr>
<td>..as long as I can choose from a variety of science topics.</td>
<td>223</td>
<td>1</td>
<td>3</td>
<td>'4</td>
<td>56</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td>..over a long period of time.</td>
<td>220</td>
<td>5</td>
<td>11</td>
<td>37</td>
<td>36</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>..if I was able to do self-reflection of my work.</td>
<td>222</td>
<td>2</td>
<td>8</td>
<td>33</td>
<td>43</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>..if I was able to work collaboratively with colleagues.</td>
<td>223</td>
<td>---</td>
<td>3</td>
<td>11</td>
<td>46</td>
<td>40</td>
<td></td>
</tr>
</tbody>
</table>
should occur over a long period of time. This could be indicative of either a discomfort with science or because of the pressure to teach so many curricular areas that teachers do not see science as important. Schibeci and Hickey (2004) reviewed elementary teachers reluctance to attend science related professional development and found that if they did not see it as relevant, they would not attend and since the primary focus in elementary schools continues to be on math and reading, they found that teachers saw little reason to attend science relate professional development opportunities.

In further trying to determine the interest in professional development activities (Table 11), 71 percent of the teachers indicated that they would be willing to attend daylong summer in-service programs, but interest decreased drastically when additional summer time was offered. Seventy-seven people offered comments about professional development and there were many valid reasons for this reluctance to “give up” additional time including the primary one being family commitments before and after school (29%). In addition, 17 of the 77 offering comments (22%) noted that the additional time would add additional stress in trying to plan for a substitute or giving up more time (referred to by some as “overtime”). Nine respondents (11%) specifically mentioned that they wanted to hold to the contractual hours and seven (9%) specified that they just had “no time.” Twelve people (15%) were very positive in their comments explaining that they were very supportive of the concept and would support efforts to improve science curriculum.

Respondents were given an additional opportunity to add other thoughts about availability for professional development and an additional 26 responses were recorded;
### Table 11. Teachers’ Availability and Willingness to Participate in Various Professional Development Opportunities Related to Science.

<table>
<thead>
<tr>
<th>Item</th>
<th>Non-responses %</th>
<th>Yes %</th>
<th>No %</th>
<th>Maybe %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Would you be willing to attend a daylong summer in-service on incorporating science inquiry in your science lessons?</td>
<td>5</td>
<td>71</td>
<td>22</td>
<td>2</td>
</tr>
<tr>
<td>Would you be willing to attend evening workshops during the school year on incorporating inquiry in your science lessons?</td>
<td>6</td>
<td>21</td>
<td>73</td>
<td>--</td>
</tr>
<tr>
<td>Would you be willing to attend a weeklong residential program focusing on science topics during the summer months?</td>
<td>6</td>
<td>16</td>
<td>78</td>
<td>--</td>
</tr>
<tr>
<td>Would you be willing to meet during the school year (eight or more times) with same grade level individuals to discuss science curriculum and ideas?</td>
<td>8</td>
<td>62</td>
<td>30</td>
<td>---</td>
</tr>
<tr>
<td><em>If yes…</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Would you be willing to meet after school hours?</td>
<td>33</td>
<td>35</td>
<td>32</td>
<td>---</td>
</tr>
<tr>
<td>Would you be willing to meet before school hours?</td>
<td>33</td>
<td>24</td>
<td>44</td>
<td>---</td>
</tr>
<tr>
<td>Would you be willing to meet during school hours?</td>
<td>30</td>
<td>58</td>
<td>12</td>
<td>---</td>
</tr>
<tr>
<td>Would you be willing to meet during in-service days?</td>
<td>--</td>
<td>97</td>
<td>3</td>
<td>--</td>
</tr>
</tbody>
</table>

*Note: Some respondents marked no the prior question, but still responded to these prompts. Their scores were also included.*
from new respondents (had not yet written anything else at this point). Most of the respondents reiterated the concern about the impact on family time, and the amount of additional time they spend on other activities. In addition, several made some interesting points. Two people commented on instruction often being too much at one time. One comment in particular, “Sometimes too much info is transmitted in one quick session – like our students we need time to assimilate new info” summed up the feeling of the two comments. On the other hand, another responder stated, “Most science development programs are too elementary/cute – need adult courses in science and not elementary discussions. I need more info/technical – my job is to redefine for elementary.” Both comments must be considered by those preparing professional development programs in order to offer a balanced program to fit the needs of the majority of the audience.

An alternative idea was raised related to meeting during the school year at least eight times with same grade level individuals of which 62 percent of the respondents were interested. Not surprisingly the two most popular choices were: meeting during school hours (58%) and during in-service (70%). Interestingly, most districts would not have eight in-service days per year, so although it is a popular choice, it may need to be combined with other options to fulfill the amount of time proposed.

Finally in Tables 12 and 13 the researcher compared the respondents’ wishes versus the respondents’ reality in relation to four statements about working collaboratively within their schools. In relation to “having time during the regular school week to work with my colleagues” 72 percent wished this was available with the reality being only 4 percent of the teachers experienced this. In relation to “sharing ideas and
Table 12. Respondents’ Desires in Regard to Collaborative Work within their Schools.

<table>
<thead>
<tr>
<th>Item (Preferences):</th>
<th>N</th>
<th>SD</th>
<th>D</th>
<th>U</th>
<th>A</th>
<th>SA</th>
</tr>
</thead>
<tbody>
<tr>
<td>I would like to have time during the regular school week to work with my colleagues on science curriculum and teaching.</td>
<td>228</td>
<td>1</td>
<td>10</td>
<td>17</td>
<td>42</td>
<td>30</td>
</tr>
<tr>
<td>I would like to regularly share ideas and materials related to science teaching with my colleagues.</td>
<td>227</td>
<td>--</td>
<td>5</td>
<td>10</td>
<td>54</td>
<td>31</td>
</tr>
<tr>
<td>I would like to regularly observe other teachers teaching science as part of sharing and improving instructional strategies.</td>
<td>227</td>
<td>2</td>
<td>6</td>
<td>24</td>
<td>47</td>
<td>21</td>
</tr>
<tr>
<td>I want to contribute actively to making decisions about the science curriculum.</td>
<td>227</td>
<td>1</td>
<td>7</td>
<td>26</td>
<td>41</td>
<td>25</td>
</tr>
</tbody>
</table>
Table 13. Reality of the Situation for Respondents within their Schools.

<table>
<thead>
<tr>
<th>Item (Reality):</th>
<th>Response Scale -- Valid Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meet with colleagues during the regular school week to work on science curriculum and teaching strategies</td>
<td>225  37  41  18  3  1</td>
</tr>
<tr>
<td>Share ideas and materials related to science teaching with my colleagues</td>
<td>226  17  41  32  6  4</td>
</tr>
<tr>
<td>Observe other teachers teaching science as part of improving strategies</td>
<td>226  73  21  5  1  --</td>
</tr>
<tr>
<td>Actively contribute to making decisions about the science curriculum</td>
<td>226  31  26  32  9  2</td>
</tr>
</tbody>
</table>
materials for science lessons,” 85 percent wished they could, but the reality is that only 10 percent do so. Sixty-eight percent wished to “observe other teachers,” but the reality is that only 1 percent was currently doing this. Sixty-six percent wished to “contribute actively to decisions on the science curriculum,” but the reality is that only 11 percent were doing so.

In the next chapter, these results will be reviewed in depth, conclusions drawn, and suggestions made for furthering the research. The teachers are interested in collaborating and working together to improve science education, but schools must be willing to build this into the teachers’ schedules so that it can become a reality. Without the financial and philosophical support of the administration, it will never happen on a large scale.
CHAPTER 5
SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

This chapter presents the summary and discussion, conclusions and recommendations of the study. It includes the purpose and objectives, procedures, summary of findings and discussion, conclusions and recommendations for further study.

Purpose and Objectives of the Study

The purpose of this study was to determine Pennsylvania elementary teachers’ perceptions and understanding of inquiry as defined by the National Science Education Standards (NSES) and advocated by the Pennsylvania Science and Technology Standards. In addition, the study was trying to determine approaches to professional development that would “fit” the elementary teachers’ schedules while achieving the goal of introducing and implementing more inquiry within elementary classrooms.

The present study was designed to address four primary questions, one of which has three sub-questions as outlined below.

1. Do Pennsylvania elementary teachers define science inquiry in a similar way as it is defined in the National Science Education Standards?
   a. How familiar are Pennsylvania elementary teachers with the Pennsylvania and National Science Standards, especially in relation to inquiry?
   b. Do Pennsylvania elementary teachers recognize the definitions of science inquiry used in the National Science Education Standards (NSES) and
Pennsylvania Science and Technology Standards (PSTS) when the definitions are stated literally?

c. Do Pennsylvania elementary teachers recognize the definitions of inquiry used in the National Science Education Standards (NSES) and Pennsylvania Science and Technology Standards (PSTS) when the definitions are stated in context?

2. What is the relationship between self-reported familiarity with NSES, recognizing NSES definitions of science inquiry literally and recognizing NSES definitions of science inquiry in context?

3. To what degree do Pennsylvania elementary teachers agree with accepted principles of effective professional development?

4. To what degree are Pennsylvania elementary teachers willing to participate in professional development activities that match accepted principles of effective professional development when the professional development is focused on science inquiry?

**Procedures**

A cross sectional survey design was prepared and pilot tested. The original survey was reviewed by members of the 2004 advisory committee for the Pennsylvania Governor’s Institute for Life Science Teachers. The advisory panel used the definitions of inquiry learning as defined by the National Science Education Standards and Pennsylvania Science and Technology Standards as their basis for reviewing the survey.
The advisory committee offered numerous suggestions about the wording of various statements in order to guard against possible bias and suggested removal of statements that they felt were inconsistent with the survey needs. In addition, the panel reviewed the statements for clarity in wording, grammar and content.

After the instrument was revised, it was submitted to the doctoral committee and additional suggestions were offered. Numerous versions were developed and a second pilot testing of the questions occurred with a convenience sampling of the elementary teachers (K-5) within my own school district.

In addition, a second panel of experts was asked to review the revised survey before it was sent out in order to further establish content validity (Trochin, 2004). The overlying question being addressed will be, “Do the statements on the survey reflect the concept of teaching science as inquiry (as defined by the NSES)?”

**Summary of Findings and Discussion**

**Demographics**

A total of 238 surveys were returned over a five-week period with 228 being almost totally or totally completed and were used to tally results. Male respondents totaled 32 (14%) and 196 (86%) were female. The majority taught in self-contained classrooms, but 30 taught in specialized classrooms with 23 explaining their area of specialty. Twelve individuals did not teach science, but did respond to most of the remaining questions based on prior experience. The respondents taught for an average of 17.29 years (see Table 3, p. 94), but the range was from a low of 1 to a high of 40 years,
representing a wide variety of experience. The mean for the number of minutes per week of science instruction was 119 minutes, but ranged from 0 to 600 minutes per week. It should be noted that four teachers specified that they specialized in teaching science and one of the schools included had a science magnet program which could explain the 600 minutes per week. Weiss et al. (2001) found in a national survey of elementary teachers that K-3 classes spend an average of 115 minutes a week on science and grades 4–6 spend an average of 155 minutes a week on science. In my study I found that the responding K-3 teachers only spent an average of 110 minutes per week on science and the grades 4-5 teachers spent 151 minutes per week on science, both slightly below the national average, but not statistically significant. Similar results for Pennsylvania schools participating for the first year (2006-07) in the Science, Its Elementary (SIE) were reported by Banilower (2007) who found prior to starting SIE, teachers reported teaching an average of 100 minutes of science a week. In the second year of the study (2007-08), Banilower, Fulp and Warren (2008) found similar results with the second cohort of participants reporting an average of 110 minutes of science instruction per week.

Use of Science Kits

I was also interested in the use of resources, specifically, kit based programs since they are widely encouraged in elementary programs. Almost half of the respondents (113; 49.6%) indicated they were using a kit-based program. Of those 113 respondents, 88 (78%) indicated they were using FOSS kits and an additional 13 (12%) marked STS kits. Additional resources mentioned by at least five respondents included: “scholastic science” and “Carroll County, Maryland curriculum.” It is not known how many are
using them as prescribed or if they are facing a similar dilemma that was indicated earlier in the literature review with individuals not using the prepared materials as originally intended (Schwab, 1978b; Rowe, 1973). Another issue with the kit-based programs is the cost of the initial kit and then the re-supply of the consumables. The question becomes who is responsible for stocking the kits and is this part of a teacher’s annual budget which has to be spread over all the curricular materials. This is a question that could be part of a further study specifically on kit-based programs.

*Science, It’s Elementary* (SIE) is a new kit-based initiative in Pennsylvania, co-sponsored by the Pennsylvania Department of Education and an outgrowth of a project done in western Pennsylvania started by ASSET, Inc which utilizes the FOSS kits and STC modules (Banilower, 2007). The project “provides participating schools with module-based science instructional materials; teacher professional development around these modules and inquiry based science teaching; and opportunities for strategic planning to help create supportive systems for science education reform” (Banilower, 2007, p. 2). The state-wide initiative began in 2006 and continues to be funded by state monies, but the cost is a factor that schools must consider. Currently, schools participating in this program are not charged, but only one elementary school per district is eligible for the state funding. If other schools within a district are interested in participating, they may be charged up to $500 per year per classroom for the kits and may be asked to pay for the additional professional development for the added teachers (ASSET website, FAQ, downloaded October 24, 2008). Is this a program that all schools can afford? And how is it being used? Are teachers just opening the kits and using them
as prescribed or are they adjusting the lessons as found in earlier research with the STS program? Banilower (2007) and Banilower et al. (2008) found that most teachers using the kits did modify the lessons, but to the detriment of the lesson; key understandings were missed in the observations of classroom instruction using the kits. He concluded, “Modifications to the lessons, often in the form of deleting probing questions or wrap-up discussions, likely hindered students’ opportunities to make sense of the target concepts” (Banilower, 2007, p. 41). Overall though, Banilower (2007) and Banilower et al (2008) found that the SIE program, using kits, significantly increased students’ understanding of science concepts compared to a control group.

Professional Development Opportunities

In addition, I was interested in whether or not the teachers had participated in any science related professional development in the past three years. One hundred thirty-two individuals (57.5%) indicated that they had participated in some form of science related professional development within the last three years, while 98 (42.5%) had not. Thirteen individuals (9.9%) indicated that the professional development was through university offerings, 24 (18.1%) individuals indicated the professional development was offered by the local Intermediate Unit and 107 of the 132 (81.1%) indicated they had some professional development related to science from their own district. Individuals were allowed to choose more than one response so there was some overlap in professional development opportunities. I did not have them indicate the length of the workshops/professional development which greatly impacts the usage in the classroom. I should also have asked if they were “mandated” to attend those workshops or was it a free-choice
offering of a variety of workshops. Both pieces of information would have been valuable in retrospect and should be included in any further surveys. Darling-Hammond and Richardson (2009) reported, “Professional development lasting 14 or fewer hours showed no effects on student learning, whereas other studies of programs offering more than 14 hours of sustained teacher learning opportunities showed significant positive effects. The largest effects were found for programs offering between 30 and 100 hours spread out over 6-12 months” (p. 49).

Banilower, Boyd, Pasley and Weiss (2006), in a ten year review of Local Systemic Change initiatives sponsored by NSF, found that teachers with at least 100 hours of science related, high quality professional development (usually based around the proper use of kits and an inquiry approach) found teachers and principals both reported a positive impact on students. The principals also “perceived their schools to be making progress in moving toward excellence in mathematics/science education and that student achievement in the targeted subject(s) was improving” (p. 64). Banilower (2007) and Banilower et al. (2008) also reported significant improvement on the post-test scores of students whose teachers participated in the *Science: It’s Elementary* professional development and utilized the kits in their classrooms compared to a control group’s post-test scores for the two years of the study currently reported. Wenglinsky (2002) also found teachers that experienced “professional development in higher-order thinking skills are more likely to have students engage in hands-on learning. Also, the more time teachers engage in professional development, the more their students engage in hands-on learning and authentic assessment. These practices are associated with student
achievement. Schools where students engaged in hands-on learning score higher on the mathematics assessment” (p. 20).

**Views of Inquiry**

The survey results indicate that the responders do identify the elements of inquiry when they see the items literally spelled out, but do not necessarily see the elements of inquiry as tied together as explained in NRC’s, *Inquiry and the National Science Education Standards* (2000). When literal examples were offered, the vast majority agreed with inquiry elements, but when asked in an open-ended format to identify the elements of inquiry they would look for in a lesson, the majority of respondents had only a basic to no understanding of inquiry, rarely identifying the various components of inquiry. The respondents fared better when looking at specific scenarios in identifying elements of inquiry.

Anderson (2007) pointed out a real dilemma in defining inquiry and understanding these results. He explained that inquiry learning is precisely defined, but the process of inquiry teaching is not so defined.

It (inquiry teaching) takes an abundance of forms, and the process of inquiry teaching is not as well understood as the desired product of these transactions, namely inquiry learning. It is also probably fair to say that a belief in the value of inquiry teaching probably carries with it a belief in inquiry learning. On the other hand, it probably is less certain that someone who understands inquiry learning as an accurate picture of how learning occurs also has equally strong convictions about the merits of inquiry teaching. In my judgment, belief in the merits of inquiry teaching among science teachers is not as strong as their belief in inquiry learning. Furthermore, common understandings of just what inquiry teaching is in practice are much more varied than understandings of inquiry learning.” (p. 810)
Anderson (2007) explained that the National Research Council’s attempts with the National Science Education Standards (1996) and the companion book, Inquiry and the National Science Education Standards (2000) do not explicitly define the theoretical aspects of inquiry, but instead present the more pragmatic examples relying instead on the work of Project 2061, Atlas of Science literacy (2001), and Science for All Americans (Rutherford & Ahlgren, 1989) to offer the theoretical basis for inquiry.

The Inquiry Synthesis Project (2006) tried to define the elements of inquiry teaching and what to look for by developing a three part framework that combines the ideas of the past 40 years into a usable table identifying the following features: Presence of Science Content; Type of Student Engagement; and Elements of Inquiry Domain. The “presence of science content” is that which the NSES identifies as physical science, life science, earth and space science and inquiry. The “Type of Student Engagement” includes the use of manipulatives; observation and the use of primary and secondary research materials. The “Elements of the Inquiry Domain present in the Components of Instruction” is actually broken into two parts with the first part being the five features of inquiry: “Question; design; data; conclusion; and communication.” According to The Inquiry Synthesis project (2006), “The second part, ‘Elements of the Inquiry Domain,’ lies at the heart of understanding the inquiry science instruction treatment. It includes three distinct elements: student responsibility for learning, student active thinking, and student motivation” (http://cse.edu.org/work/reasearch/inquirysynth/technical report2.pdf, retrieved: December 29, 2008). This distinction could be compared to the chart introduced by NRC in 2001 in Inquiry and the National Science Education
Standards which offered a continuum of inquiry from teacher directed to student directed inquiry (see Table 1, p. 3). This is an area that calls for more research as we try to determine and define more clearly the theoretical aspect of what is inquiry teaching and determine if The Inquiry Synthesis Project (2006) table is a better measurement tool than the table offered by the NRC.

A key factor in inquiry as defined in the NSES is the opportunity to discuss and communicate results, justifying the responses with scientific evidence. In scoring teacher responses, I did give communicating results more weight in the scoring rubric – the respondents received one point for identifying each of the first four parts of inquiry and a two points if they specified in any way discourse or discussion of results (Appendices C & D). Discourse in science inquiry should be a primary feature of future science education research in elementary and secondary science. Carlsen (2007) pointed out, “The science classroom sits on the border between competing cultures, such as the scientific community, which values open inquiry and disagreement, and the formal school community, which generally prefers quiet obedience” (p. 60). I wonder now how many respondents also lean toward the “quiet obedience” for their classrooms.

Although a good majority of the teachers identified the concept of discussing or sharing results in the final two open-ended scenarios, it is interesting that only 18 percent mentioned this as a feature they would look for in observing a lesson and determining if it was inquiry based or not. In addition, no one specified that the discussion or sharing of results should be tied to evidence gathered. Rutherford and Ahlgren (1989) in their groundbreaking work, Science for All Americans, suggested that students are thought to
understand concepts if they use the “right words,” but are often found to have only memorized information without a clear understanding of the concept. Employing the process of discourse, if applied correctly, would ensure that students comprehend the information and have a clear understanding of the concepts, but only if the teacher and other students are listening to and are prepared to “challenge” the argument presented. Carlsen (2007) suggested that teachers tend to practice controlled discourse, “Traditional teaching is characterized by an asymmetry of conversational rights that favor the teacher…. And when teachers find themselves discussing unfamiliar subject matter, they may rely upon questioning to prevent the topic of discussion from wandering into uncomfortable territory” (p. 62). This may be especially true of the elementary teacher who has to be an “expert” in all the subjects s/he is assigned to teach.

Often in the process of a discussion, misconceptions are revealed which can lead to an inquiry investigation. If students are permitted to challenge and are challenged to defend their responses with scientific evidence, we will achieve the goal of a more literate science consumer (NRC, 1996). But if we just allow students to “report” their findings and do not challenge them to delve deeper to truly understand the concepts we will continue to think that students understand because they “use the right words as evidence of understanding” (Rutherford & Ahlgren, 1989, p. 187). Unfortunately, this is also where elementary teachers feel less qualified, unsure themselves of the “why” behind how something works or reacts. Kelly (2007) shared some of the findings of Gallas’ work with “science talks” which invite the students (first and second graders) to share what they know and helps to highlight misconceptions they may have. It also
invites students to identify areas for further inquiry so they can learn more about a topic. Kelly wrote, “The description of these experiences in Talking Their Way into Science: Hearing Children’s Questions and Theories, Responding with Curricula represents a break in the typical power asymmetries found in science classroom discourse” (p. 448).

Klein (1998), very critical of textbook type lab reports, also warned that students can make causal inferences and may correctly identify issues and answers without having to justify the response. If students are not challenged to share their results and truly engage in discourse, they may walk away with the right answers, without knowing why. Kelly (2007) also pointed out studies that “revealed that students assigned audience roles during spoken reporting sessions initiated more engagement episodes and challenges without such role assignment” (p. 451). If we could intentionally direct the conversations so that students were more willing to listen and challenge each other’s findings, using evidence as a basis for the challenge, we could be assured that the students had a deeper understanding of the science and not just a case of using the “correct” words to determine knowledge. But the teachers must also be comfortable with the information. One observer of a SIE professional development training session which was introducing the concept of Pedagogical Content Knowledge (PCK) noted, “Participants did not understand the science content well enough to fully understand what student thinking was scientifically accurate and what thinking was inaccurate” (Banilower et al., 2008, p. 37).

Furthermore, Banilower et al. (2008) found that even in the second year of using the kits, SIE teachers were still at a mechanical level of delivering the kit material and identified common areas of weakness as being that the students were engaged with
hands-on, but not necessarily minds-on activities. “Students engaged in many hands-on activities, but the amount of intellectual rigor required of the students in most lessons was generally low. Many teachers made modifications to the instructional materials, often in the form of deleting questions or wrap-up discussions, which likely hindered students’ opportunity to make sense of the target concepts” (p. 60).

Future professional development training for teachers and administrators should not only focus on the science content, but on the process of engaging students in evidence-based discourse. Teachers first must be comfortable with this process and see the value of teaching students to not only share results, but ensure those results are based on evidence from the research. In addition, students must learn to listen to their peers’ descriptions and be willing to challenge results, again basing it on evidence, and not just a feeling or assumption they hold. The students must also learn to look for alternative theories that fit within the accepted standards of science to explain results. This will be a major adjustment in many classrooms as students take control of the learning. Learning the process of respectful dialogue will be a challenge to embrace, and will not occur overnight. It will be a long process that must embrace the culture of the school and community. If students were exposed to this process throughout their elementary years, they would expect this to continue into their secondary schooling and beyond. These would be life-long skills that would reach beyond science understanding into their lives and would also achieve the goal of having a more literate science community.
Familiarity with Standards

In relation to self-reported familiarity with the National Science Education Standards and the Pennsylvania Science and Technology Standards and the Pennsylvania Environment and Ecology Standards, I found a vast majority reported familiarity with the Pennsylvania Science and Technology standards which specifically spell out inquiry and design (Standard 3.2), but less than half were familiar with the Environment and Ecology (the second part of Pennsylvania’s science standards) and the National Science Education Standards which also spell out the elements of inquiry. But, in general, I found no significant difference or pattern between those who said they lacked understanding and those who said they were familiar with the standards in terms of their literal recognition of the elements of inquiry or in their recognition of the elements of inquiry in context.

Professional Development

The vast majority of teachers agreed with the accepted principles of professional development, but on the other hand they also agreed with contradictory statements offering one-to two day sessions and “menu-driven” opportunities of 1, 2 and 4 hour sessions. In addition, they also agreed that flex-time offering time to work in classroom preparation was a high quality professional development opportunity. This could indicate an overall dissatisfaction with current professional development programs as they are currently conducted and the ever present desire for more “time” in their own individual classrooms. It could also be they were experiencing survey fatigue and just responded in the affirmative without reading the statements. This is an area that needs further exploration. Interviews of individual teachers might have clarified the issues.
If teachers are “forced” into professional development they have no input in designing, they may not see the importance of the programming. Further research should explore the amount of input teachers have in designing professional development opportunities and the amount of information they receive ahead of time to prepare for the professional development. If it is just a one- or two-day focus, the interest may not be there to pursue it further, but if it is a district–wide, year-long or three-year long initiative that teachers have had input in implementing, they may take ownership in the design and success of the programming.

Wei, Andree and Darling-Hammond (2009) reported on other nations who have achieved high success on the international scale by using Professional Learning Communities that stress a collegial working relationship and empowering teachers to make changes. Hargreaves in 1994 wrote, “If restructuring is, in some fundamental sense, about the reconstruction of school power relationships, then we would expect the working lives of teachers to be organized not around principles of hierarchy and isolation, but ones of collaboration and collegiality” (p. 244). Hargreaves (1994) also wrote, paraphrasing Sarason’s work, “If components like curriculum change, professional development, or new teaching strategies are tackled in isolation while others are left unchanged, ... the success of the reforms will almost certainly be undermined” (p. 242). If teachers are not empowered to be part of the decision making body, they most likely will not implement the change needed and will continue to work in isolation.

The success of any professional development initiative is based on buy-in from all sectors – the teachers, the administration and the community. It must be a long-term
commitment (3-5 years minimum) that is not just filled with more meetings, but has a focus and purpose. The professional development approach must take into account the climate and culture of the school – determining what is important and what can be adjusted. It must be considered a part of the scheduled day and not an additional “tacked-on burden” at the end of the day. If the U.S. is serious about changing the face of how well our students score on science and math related international tests, we must also be willing to review what has worked in other countries. Dedicated time for actual teacher collaboration on subject content and pedagogy throughout the school day is a key factor in the successful schools.

In their responses to willingness to participate in professional development related to science inquiry, the majority of teachers were in agreement, but three statements received lower than expected scores because similar statements were considered much more valuable in the general professional development section. The three statements related to developing science leadership skills; self reflection; and administrative (principal) participation in science professional development. In the overall features of professional development (see Table 9, p. 109), 78 percent agreed or strongly agreed with leadership development, but only 56 percent agreed that it was important in science professional development, yet, 76 percent also agreed that they would attend science professional development if their colleagues were presenting (see Table 10, p. 112). This could be indicative of a lack of confidence in their own science abilities and a “fear” of sharing what they are doing, but they want their colleagues to do so. Follow-up interviews may have clarified this issue. This is also where programs like “Lesson
Study” or “Critical Friends Group” might help boost the confidence of teachers – they will realize they are not alone, but that working together they can generate new ideas and try new approaches. Time throughout the day or compensated time at the beginning or the end of the day might encourage teachers to participate. If they see the value and are respected for their time and experience, they may be more willing to actively participate.

In terms of self reflection, 87 percent saw the value in the general aspects of professional development, but when self-reflecting specifically on science, the percentage dropped to 57 percent. It would be interesting to see if the same would hold true in a subject they felt confident teaching such as reading or math. Akura (2004) found self-reflecting over a long period of time facilitated change in elementary teachers, but they must be encouraged to do so. If done in conjunction with a collaborative team effort, self-reflection can be a very powerful tool. Having the opportunity to individually reflect on the strengths and weaknesses of a lesson and then sharing ideas and listening to others’ thoughts on the program can be very powerful and beneficial for all parties. Unfortunately, typically the only time that the strengths and weaknesses of a lesson are discussed is with the principal in an evaluation mode based on an observation, which leads to the potential reluctance of teachers to include the principal in the professional development training.

The third statement that received only 33 percent agreement was that the principal should be involved. Principals should show their interest and support of their teachers’ professional development. By attending and participating, the principal is in effect telling the teachers that the professional development is important and he or she will support
their efforts. If involved, the principal will also know what to look for and encourage
when evaluating teachers that are stretching outside the box and trying to engage students
in new ways. If the principals are not aware of the efforts, they may circumvent the
efforts. Jorgenson (2001) stated, “It is critical that responsible administrators actively
and regularly join in the experience. To be successful in providing academic preparation
for students, a program must work through the school system, with the full support and
endorsement of the superintendent and the school principal” (p. 130). The principal, as
the primary educational leader, must demonstrate the same commitment being asked of
the teachers. On the other hand, teachers may view this as a threat or a challenge to their
autonomy in the classroom since the principal is also the primary evaluator of their work.
This is where a collaborative, working relationship with the educational leader is
essential and involves the culture and climate of the school.

A vast majority again thought time working in their room individually was very
important, but less than half felt professional development related to science should occur
over an extended time period. Wei et al. (2009) reviewed professional development
opportunities provided for teachers in countries achieving high scores on the international
tests (PISA and TIMSS) and they found common threads in the professional development
offered to teachers including:

- Time for professional collaboration built into the teacher’s work hours.
- Ongoing professional development activities that are embedded in teachers’
  contexts and focused on the content to be taught.
- Extensive opportunities for both formal and informal in-service development.
• Supportive induction programs for new teachers.
• School governance structures that involve teachers in decisions about
curriculum, instruction, assessment and professional development” (p. 29).

Until we break out of the mold of only offering one or two day workshops and
offer teachers the opportunity to take charge of their learning, and offer them time in their
day to plan together and enhance their understanding of the content and gain confidence
in their teaching of a subject that they lack comfort with, we will continue to struggle
with teachers who only want short term professional development or time to work in their
rooms. Wei et al. (2009), reporting on the high achieving countries identified through the
international assessments, wrote, “In most European and Asian countries, less than half
of the teacher’s working time is spent instructing students... The rest – generally 15–20
hours per week – is spent on tasks related to teaching, such as working with colleagues
on preparing and analyzing lessons, developing and evaluating assessments, observing
other classrooms, and meeting with students and parents” (pp. 29–30).

Two key findings of 2009 National Staff Development Council Report were:
1. Effective professional development is intensive, ongoing, and connected to
practice; focuses on the teaching and learning of specific academic content; is
connected to other school initiatives; and builds strong working relationships
among teachers. However, most teachers in the United States do not have
access to professional development that uniformly meets all these criteria.

2. While teachers typically need substantial professional development in a given
area (close to 50 hours) to improve their skills and their students’ learning,
most professional development opportunities in the U.S. are much shorter (Darling Hammond et al., 2009, p. 5).

Fulp (2002) reported that, nationally, collaboration with peers is the second most common form of professional development nationally with approximately 33 percent of responding elementary teachers observing each other and 27 percent meeting regularly to discuss science teaching. In my results though, I found only 1 percent was observing each other, although 68 percent indicated that they would like to do this and only 4 percent were meeting regularly with colleagues to discuss science curriculum, although 72 percent indicated that this would be desirable. Desimone et al. (2002) suggested that study groups, teacher networking, mentoring relationships, committee or a task-force are all possible avenues for encouraging further professional development and the teachers appear to desire this type of reform. With strong leadership, the potential for engaging adult learners would be endless, but again, limitations of time and monetary resources might hinder these efforts.

Each school must decide as a community which plan would work for them – and it is possible that small groups within a school might use different approaches. Various approaches should be presented with the pros and cons including Lesson Study, Critical Friends Group and Professional Learning Communities. The teachers themselves should choose the program they feel best fits their learning goals and commit themselves to a 3–5 year plan. Training of key leaders is essential once the plan(s) are chosen, but the leaders should be chosen by the teachers, not by administrators. If teachers are respected
for their professionalism, they will commit to the program. School districts must realize that this will mean more time and resources and they must be willing to commit to it too.

Chokski and Fernandez (2004) in surveying lesson study groups found most groups desired the interaction at least once a week. By assigning specific responsibilities and distributing materials ahead of time, the study group’s time was maximized, but strong leadership will be essential to keep the group on track. Professional Learning Communities (PLC) which have been gaining a lot of popularity in theory, sometimes find that they are “stalled at the stage of collegial discussions about improving teaching practice” (Smith, Wilson & Corbett, 2009, p. 20). Smith et al. reported on three urban districts in New Jersey that moved past this when they used, “Coaches from the National School Board Reform Faculty who trained internal facilitators in these schools, who in turn launched collaborative learning communities (CLCs) among their peers” (p. 20). The researchers wrote, “Through summer retreats, school-year seminars, and school-based meetings we saw participants acquire the confidence and ability to nurture self-sustaining communities” (p. 20). Six conditions continually came up as the key to successful CLCs, “a preexisting supportive culture, time to meet, satisfying processes, voluntary participation, support from principals and a cadre of trained facilitators” (Smith et al., 2009, p. 21).

Delving further in the survey, I tried to find times that would be acceptable to the respondents to work on science professional development. Daylong summer activities were acceptable, but as soon as the time was extended, the desire dropped drastically. Reasons for this varied from family obligations to contractual time. An alternative was to
meet during the school year. Two options proved to be the most popular, meeting during the school day (58%) and meeting during in-service days (70%). A number of teachers did not like the suggestion of meeting during the school day since they didn’t like to leave their students for extended periods of time. Boyd et al. (2003) recommended that at least a week-long summer program backed up with meetings throughout the school year will render the best results, but realizes that this is not always possible due to family and other commitments.

If we review the European and Asian models of the most successful programs though, we should be looking at offering this time to the teachers during the school day to meet and work cooperatively. This time commitment should be scheduled so that teachers are leaving their children and a substitute is called in, but rather other full-time teachers are in charge of the students in those classes while the small group of teachers can meet – this opportunity must be designed for all teachers in the school. This is not a change that can happen quickly, but rather the culture of the school and community will have to change to accept this new direction. It will require additional monetary resources and a commitment from the overall community, including the parents, administrators, teachers and children.

Conclusions

The results indicated that the elementary teachers in this part of Pennsylvania are not that familiar with the National Science Education Standards document that is over ten
years old, nor the Pennsylvania Environment and Ecology standards, but they are more familiar with the Pennsylvania Science and Technology Standards.

If presented in a literal sense, the teachers appear to have a good view of inquiry and can identify the elements of inquiry, but the question remains, are they employing inquiry lessons? The response is “probably not” since they are spending so little time with science lessons: K-3 spending an average of 22 minutes a day on science and 4-5 graders spending only 30 minutes per day on science, both slightly below the national average. Instead, the teachers are concentrating on other curricular topics, primarily math and reading. If we could offer teachers an alternative that would use inquiry based science as the primary focus to teach math and reading, I strongly believe that students would not only see the ultimate value of reading and math since it would be applicable immediately, I believe test scores would rise and student interest in school would also increase. In addition, the process of evidence-based discourse is a skill that can cut across disciplines, but logically fits easily in an inquiry based science program.

Both Banilower et al. (2007, 2008) and Wenglinsky (2002) were able to correlate increased test scores with teacher participation in long-term professional development programs, but at this point the teachers are not committed to giving up the time. Teacher professional development for too long has been one and two day workshops that teachers must “endure,” but if we can change the current mind-set and learn from the highest achieving countries, studying their methods of professional development, and employing the successful models we could turn this around.
But this highlights the next issue in relation to elementary teachers willingness to participate in science based professional development. Although the elementary teachers were able to recognize the qualities of good professional development, they also identified factors that contradicted high quality professional development. These factors included the short-term opportunities which may indicate that teachers, not sure if they like something, figured that it won’t last long (no long term commitments). In addition, they felt that flex days or trade days and time to work in their room prepping the room should count as high quality professional development opportunities. I believe that they know these truly are not professional development opportunities, but rather reflect their frustration over a lack of time to accomplish these tasks throughout the normal work day.

Banilower (2007) quoted one teacher in commenting about the SIE professional development in relation to using the kits explaining that the presenters did not share the amount of time involved in preparing the inquiry experiments, “The experiments, material wise, are overwhelming. It took a lot of preparation. All of my planning time was spent on setting up, and my paperwork is not getting done” (p. 14). Combining a lack of comfort with the science material, the increasing amount of administrative paperwork required of teachers and the accountability in this technology savvy environment to continually update student progress on the parent connection websites in many districts, the teachers are overwhelmed by the amount of time and are more willing to put it off rather than commit the time needed to fully engage students in an inquiry driven science curriculum. Elementary teachers are expected to be experts in many areas and are feeling increasing pressure for their students to succeed on standardized tests.
Again, the opportunity for collaboration with peers in lesson study, critical friends groups or professional learning communities, if managed correctly, will help alleviate the fears many experience with learning the science content and new approaches to teaching. If the teachers begin to see the success in their classrooms with the students, they will be more willing to try more approaches that can make a difference. It is crucial that we do not try to change everything at once, but instead focus on one or two units of study throughout the year.

The responding teachers were more reluctant to agree to professional development opportunities specifically related to the sciences. Schibeci and Hickey’s (2004) report also indicated elementary teachers’ reluctance to attend science related professional development, finding that if the teachers did not see the professional development opportunity as relevant to them, they would not attend. Since the primary focus in elementary schools continues to be on math and reading, they found that teachers saw little reason to attend science related professional development opportunities. I would further contend that the lack of comfort with science related subjects makes some teachers pause before committing the time if other offerings are also available. It is human nature to gravitate to areas where you are comfortable and the majority of elementary teachers are not comfortable with delving into science. Long-term professional development is the only way we will be able to improve the current situation, but time, money and willingness to participate are all vital components.

If a school district is fortunate enough to be close to a college or university, professional development communities might be established that would further enhance
the in-service learning and assist with the pre-service teachers' experiences in a positive format, but not all districts are situated close to nor have the desire to work with higher educational institutions, and not all higher education facilities have the faculty and money to devote to this endeavor.

More research in the implementation of Collaborative Learning Communities is needed to encourage more schools to participate. Research on the success of the professional development opportunities in the highest achieving countries must also be accessible for the general practitioners who might be willing to take the challenge and start CLCs in their own schools, but again time and money commitments from the local community will be needed. Teachers are already over-burdened with new initiatives and programs, in addition to trying to stay on top of daily paperwork and unless a long-term commitment for reform is made and adopted by all members of the community, it is bound to fail. The reform must be a joint effort of teachers and administrators, working with the general public to understand the need for the reform in order for success to be achieved. If the administration does not have teacher support for the initiative, it will fail and if the teachers do not have administrative support, it is doomed to fail. But the public also has a part and must be kept informed because public opinion can also doom a project.

There is no easy answer. The culture of teaching and the commitment of life-long learning are essential ideals to instill in all who choose to enter the teaching profession and must be revitalized in those currently practicing. For too long professional development has been viewed by teachers as something to endure. Ferriter (2009) wrote,
“(Teachers) are largely unwilling to challenge the status quo. ‘Nothing’s going to change,’ they insist. ‘This is how professional development has always been done. Just bring a big stack of papers to grade, and you’ll keep busy.’ A history of poor professional development experiences has left them jaded and stagnant, groaning when given ‘opportunities to learn’” (p. 35).

But we cannot give up – professional development opportunities need to be available and enriching and must have the support of all parties involved. It can no longer be something teachers endure, but rather something they look forward to attending, realizing that ultimately it will benefit their students. Lessons from other countries must be studied and each school in every district must be willing to set aside the past bad experiences and look toward the future. Collaborating on lessons, sharing ideas, observing one another, and sitting down and having honest conversations about the observations in a non-threatening environment are the only ways to move forward. We cannot be left behind in the areas of science and math as is currently occurring. We need to be honest with ourselves and begin to look at new ways of approaching the problems. Teaching students the process of science inquiry and following up with evidenced-based discourse will only promote problem-solving individuals who are more willing to tackle new learning with enthusiasm.

**Recommendations for Future Research**

Based on the findings, conclusion and discussion, the following are recommendations for possible further research.
1. Validation of alternative assessment instruments to determine if students are truly understanding the science or just memorizing information and using the “right” words. A comparison study of the NRC’s table of Inquiry and the Inquiry Synthesis Project table might be used as an assessment tool by fellow teachers or principals in observing lessons.

2. Directed interviews and observations of successful elementary teachers implementing more science inquiry and evidence-based discourse in their lessons and connections to make these lessons more accessible for practitioners to study and discuss, figuring out how they might implement these ideas.

3. Longitudinal studies of individual teachers succeeding in sparking the interest in science for students. Are these teachers employing the elements of inquiry and if so how, and are they even aware of what they are doing? Are they teaching evidence-based discourse? If so, how and what are the students’ long-term successes that might be linked back to it?

4. Continuing research on how teachers learn and its impact on professional development opportunities related to science inquiry learning and the process of evidence-based discourse. Smith and Desimone (2003) questioned the effectiveness of professional development and whether it addresses teachers as learners. We need to re-think the methods continually being employed and “fight back,” and encourage teachers to “challenge the status quo” (Ferriter, 2009, p. 35).
5. Continuing research on correlating scores to determine the long-term professional development training of teachers in science inquiry and evidence-based discourse the ultimate impact on students.

6. Continuing research on model elementary science professional development programs in the U.S. to see what enables teachers to make the long term commitment to science professional development.

7. Continual research in studying the professional development models in highly successful schools in other countries.

8. Long-term, high-quality professional development specifically in science content, inquiry learning and especially highlighting the value of teaching evidence-based discourse.

9. Recognize the role of the principal as an educational leader and not just the evaluator of teachers. Include the principal in the learning process and encourage him or her to also teach a class throughout the year (one period a day) to keep in contact with the role teachers face. If teachers see that the principal is also one the “front lines” and is struggling with implementing new ideas, and collaborating as a learning partner and not just the “evaluator,” they may be more willing to go to the principal for ideas and suggestions. The dialogue will be more inviting and understanding.
REFERENCES


http://eric.ed.gov/ERICDocs/data/ericdocs2sql/content_storage_01/0000019b/80/29/d7/d4.pdf


Downloaded June 29, 2004 from


Appendix A

INFORMATION SHEET REGARDING SCIENCE TEACHING
I am a doctoral student at The Pennsylvania State University and a full-time middle school science teacher at Lower Dauphin Middle School. I just finished a year-long sabbatical and am completing my studies with this research project sponsored by Penn State.

You have been randomly selected to complete the attached survey. The survey will take approximately fifteen minutes to complete and can be returned in the pre-stamped, addressed envelope provided. All participants must be at least eighteen years or older to participate in this study.

The following information is being provided in lieu of participants having to sign an informed consent document. By completing the survey, you are giving your implied consent realizing that the completion is entirely voluntary. You may decline to answer specific questions.

If you have any questions or concerns, please feel free to contact Kathleen Jones or Dr. James Nolan. If you have questions regarding your rights as a research participant, please contact the Office of Research Protections at 814-865-1775.

**Purpose of the study:** To determine elementary teachers’ perception of inquiry within their classroom when they teach science. In addition, I am trying to determine the interest in professional development opportunities for incorporating more inquiry in elementary and middle school science classrooms.
Confidentiality statement: Demographic information is being requested but cannot personally identify your response. If this research is published, no information that would identify you will be written since your name is in no way linked to your responses. The Office for Research Protections may review records related to this project. All surveys will be kept in strictest confidence.

Discomforts or risks: No risk, above that experienced in every day life, is expected as a result of your participation in this research project.

Benefits: Using inquiry to teach science has been encouraged, but not everyone is comfortable with the concept. Part of the research will also be to determine the type of professional development that teachers might be willing to participate in to sharpen their inquiry skills in the classroom.

Summary of results: If you are interested in receiving a summary of the results from the surveys, please send an email to kmj101@psu.edu and a summary of the results with analysis will be emailed back upon completion of the study.

Again, thank you for your time and attention to this matter. Your completion of the survey is greatly appreciated. I have enclosed two first-class postage stamps as a small thank you for your cooperation and attention to this survey. I hope you find the postage stamps useful. In a few weeks, a reminder will be emailed asking you to return the survey if you have not yet done so. Your time and consideration are greatly appreciated. Please keep this copy for your records or future reference.

This consent form (IRB#19196) was reviewed and approved by the Office for research Protections at The Pennsylvania State University on July 11, 2005 (DWM). It expired on July 10, 2006 (DWM)
Appendix B

ELEMENTARY TEACHER SURVEY REGARDING SCIENCE TEACHING
ELEMENTARY SCHOOL TEACHER SURVEY
REGARDING SCIENCE TEACHING

This survey is to assess the level of understanding related to inquiry and the national and state standards. Some of the statements are taken from the 2000 National Science and Mathematics Education Survey, Horizon Research, Inc. All information will be kept in the strictest of confidence and used only to determine needs for future training. By completing the survey and returning it to Kathleen M. Jones, principal investigator, you are giving your implied consent to use the information for research purposes. Thank you for your cooperation. Additional information detailing the research can be found on my website: www.missjonesscience.com.

The survey is broken up into a series of categories; some that require a numerical value and others that require a brief response. Your assistance in completing this survey is greatly appreciated.

Section 1: GENERAL INFORMATION

1. Gender ___ Male
   ___ Female

2. How many years have you been teaching (at the end of this year)? _____ years

3. What grade level(s) are you teaching this year? ______

4. Do you teach in a self-contained classroom? ___ Yes
   ___ No
   If no: list the area(s) you specialize in teaching: _______________________________

5. How many minutes per week (on the average) are used for science? _____ minutes

6. What is/are your certification area(s)? Check all that apply.
   ___ Elementary certification
   ___ Early childhood
   ___ Other (please specify) _____________________________________________

7. Are you using any kit-based program currently in your science curriculum?
   ___ Yes
   ___ No
   If yes, please specify:
     ___ FOSS
     ___ STS
     ___ Other (please specify) _____________________________________________
8. In the past three years, have you attended any professional development programs related to science?
   ___ Yes
   ___ No
   If yes, please check the type(s) that apply:
   ___ University-sponsored course
   ___ IU offering
   ___ District in-service
   ___ Other (please specify) ________________________________

Section 2: TEACHER OPINIONS

Determine your response to each statement and circle the appropriate number using the following scale: 1-Strongly Disagree (SD); 2-Disagree (D); 3-Undecided (U); 4-Agree (A); 5-Strongly Agree (SA). As a guide to the meanings for the numerical rankings, please consider the following example: If the statement were “pepperoni is the best topping for pizza” and you hate pepperoni pizza, you would strongly disagree (1). If you feel pepperoni pizza is okay, but you really prefer other toppings better, you might disagree (2). If you were undecided, that would be (3). If you think pepperoni is ONE of the best toppings for pizza you would agree (4), and if you think pepperoni is the BEST topping you strongly agree (5).

   |   |   |   |   |   |
---|---|---|---|---|---|
9. Library research could be a part of inquiry-based lessons           & SD & D & U & A & SA \\
   |   |   |   |   |   |
10. Web resources/research could be a part of inquiry-based science lessons. & 1 & 2 & 3 & 4 & 5 \\
   |   |   |   |   |   |
11. I would like to have time during the regular school week to work with my colleagues on science curriculum and teaching. & 1 & 2 & 3 & 4 & 5 \\
   |   |   |   |   |   |
12. I would like to regularly share ideas and materials related to science teaching with my colleagues. & 1 & 2 & 3 & 4 & 5 \\
   |   |   |   |   |   |
13. I would like to regularly observe others teachers teaching science as part of sharing and improving instructional strategies. & 1 & 2 & 3 & 4 & 5 \\
   |   |   |   |   |   |
14. I want to contribute actively to making Decisions about the science curriculum. & 1 & 2 & 3 & 4 & 5
**Section 3: IMPORTANCE OF CLASSROOM COMPONENTS**

As students work on a science investigation, how important are the following components for your classroom? Each statement should be rated on the following basis: 1-Very Unimportant (VU); 2-Somewhat Important (SI); 3-Unsure (U); 4-Somewhat Important (SI); 5-Very important (VI).

<table>
<thead>
<tr>
<th></th>
<th>VU</th>
<th>SU</th>
<th>U</th>
<th>SI</th>
<th>VI</th>
</tr>
</thead>
<tbody>
<tr>
<td>15. Students are engaged in answering a scientifically oriented question.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>16. Students should be encouraged to develop their own scientific question.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>17. Students are encouraged to find and use scientific evidence through research and/or experimentation to answer the guiding question.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>18. Students should formulate explanations from evidence collected through research and/or experiments.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>19. Students should be encouraged to connect explanations with prior science knowledge.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>20. The majority (70% or more) of time students should share their findings and justify the explanations only to the teacher in the form of a report or lab sheet.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>21. The majority (70% or more) of time students should share their findings and justify the explanations to a small group within the class.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>22. Students should complete a formal lab report using the prescribed scientific method.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>23. Students should consider alternative explanations and solutions.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>
Section 4: STATE AND NATIONAL STANDARDS

24. How familiar are you with the PA Science and Technology standards?
   ___ 1. Never heard of them
   ___ 2. I know of them, but don’t use them
   ___ 3. Familiar and have referred to them
   ___ 4. Very familiar and refer to them frequently

25. How familiar are you with the PA Environment and Ecology standards?
   ___ 1. Never heard of them
   ___ 2. I know of them, but don’t use them
   ___ 3. Familiar and have referred to them
   ___ 4. Very familiar and refer to them frequently

26. How familiar are you with the National Science Education standards?
   ___ 1. Never heard of them
   ___ 2. I know of them, but don’t use them
   ___ 3. Familiar and have referred to them
   ___ 4. Very familiar and refer to them frequently

Section 5: PROFESSIONAL DEVELOPMENT

The following only require a yes or no responses with an opportunity to add comments.

27. Would you be willing to attend a daylong summer in-service on incorporating science inquiry in your science lessons? Y N

28. Would you be willing to attend evening workshops during the school year on incorporating inquiry in your science lessons? Y N

29. Would you be willing to attend a weeklong residential program focusing on science topics during the summer months? Y N

30. Would you be willing to meet during the school year (eight or more times) with same grade level individuals to discuss science curriculum and ideas? Y N

   If Yes,
   a. Would you be willing to meet after school hours? Y N
   b. Would you be willing to meet before school hours? Y N
   c. Would you be willing to meet during school hours? Y N
   d. Would you be willing to meet during –service days? Y N

Why or why not? ___________________________________________
31. Please feel free to add any comments or thoughts you may have about availability for professional development opportunities:

Please rate the following statements related to High Quality Professional Development (HQDP) using the following scale: 1-Strongly Disagree (SD); 2-Disagree (D); 3-Undecided (U); 4-Agree (A); 5-Strongly Agree).

32. High Quality Professional Development…

   a. focuses on both specific subject matter and the strategies to teach it. 1 2 3 4 5
   b. actively engages teachers in the same type of learning activities they are expected to take back into the classroom. 1 2 3 4 5
   c. would provide opportunities to connect concepts to the curricular materials the district has. 1 2 3 4 5
   d. can occur in one- or two-day in-service programs. 1 2 3 4 5
   e. creates opportunities for teachers to serve in leadership roles and share their expertise with colleagues. 1 2 3 4 5
   f. includes support from administrators as teachers attempt changes in the classroom 1 2 3 4 5
   g. includes flex days or trade days that allow you time to work individually in preparing your classroom. 1 2 3 4 5
   h. includes “menu” opportunities for 1, 2, or 4 hour sessions on a variety of topics. 1 2 3 4 5
   i. is a long-term process. 1 2 3 4 5
   j. provides opportunities for self-reflection. 1 2 3 4 5
   k. provides opportunities for collaborative work with colleagues 1 2 3 4 5
   l. provides structures and strategies that allow teachers to learn from their daily teaching practice. 1 2 3 4 5
33. I would be willing to participate in professional Development related to science…

<table>
<thead>
<tr>
<th></th>
<th>SD</th>
<th>D</th>
<th>U</th>
<th>A</th>
<th>SA</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. to increase my science knowledge.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>b. to improve my science teaching techniques.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>c. that uses learning activities similar to those that I would be expected to use with my students.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
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<tr>
<td>d. that focuses on the curriculum in my district.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
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<tr>
<td>e. as long as it is a day-long in-service, once or twice a year.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
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<tr>
<td>f. to develop leadership skills in science education.</td>
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<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>g. in which colleagues who have expertise serve as workshop leaders.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>h. if my principal also participated in the workshop activities.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>i. if it meant having time in my room to work individually.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>j. as long as I can choose from a variety of science topics.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>k. over a long period of time.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>l. if I was able to do self-reflection of my work.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>m. if I was able to work collaboratively with colleagues.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
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</tbody>
</table>
Please rate the following statements using the following scale: 1-Never (N); 2-Rarely (R); 3-Sometimes (S); 4-Often (O); 5-All or almost all (A).

34. How often are you able to do the following professional development activities?  
   N  R  S  O  A
   a. Meet with colleagues during the regular school week to work on science curriculum and teaching strategies.  
      1  2  3  4  5
   b. Share ideas and materials related to science teaching with my colleagues.  
      1  2  3  4  5
   c. Observe other teachers teaching science as part of improving strategies.  
      1  2  3  4  5
   d. Actively contribute to making decisions about the science curriculum.  
      1  2  3  4  5

   Section 6: SHORT RESPONSE AND SCENARIOS

35. If you were observing a science lesson in the elementary classroom, what specifically would you look for to determine if it was an inquiry-based lesson or not an inquiry-based lesson?

36. Scenario #1: Mr. Smith’s class is up, moving around to various lab stations, doing “hands-on” activities, exploring simple machines. At the end of the class, Mr. Smith collects all the worksheets and the students move to the next subject.
   a. Is this an inquiry lesson? Explain your response.

   b. What do you think happened prior to this lesson?

   c. What do you think will happen tomorrow in science class?
37. Scenario #2: As you walk into Mrs. Brown’s class you observe a question on the board, “What do owls eat?” Some students are working on the computer assessing the Internet about owls, others are using the class library to find books on owls and another group are pulling apart owl pellets, categorizing and identifying the various bones.

a. Is this an inquiry lesson? Explain your response.

b. What do you think happened prior to this lesson?

c. What do you think will happen tomorrow in science class?
Appendix C

SHORT RESPONSE QUESTION RUBRIC
SHORT RESPONSE QUESTION RUBRIC

Using the five elements of inquiry and assigning them a value as follows:

Essential features named:
1. Engaged in a question (1 point if included, 0 if not included)
2. Priority given to evidence (1 point if included, 0 if not included)
3. Predications, descriptions, explanations using evidence (1 point if included, 0 if not included)
4. Connects evidence and explanations to developing scientific knowledge (1 point if included, 0 if not included)
5. Engages in discourse (2 points if included, 1 point if only suggests “reporting” and does not indicate the justification of response, 0 if not included)

I weighted the discourse statement more because I see it as one of the vital components of inquiry, yet one that is often neglected. The total possible points are 6 and were re-scored to a 5 point scale using the following:

A score of 5 – 6 indicates an excellent understanding of inquiry as defined by NSES and is scored as a 5.
A score of 3 - 4 indicates a good understanding of inquiry as defined by NSES and is scored as a 4.
A score of 2 indicates a basic understanding of inquiry as defined by NSES and is scored as a 3.
A score of 1 indicates very little understanding of inquiry as defined by NSES and scored as a 2.
A score of 0 indicates an attempted response made, but too the response was too general in nature and did not indicate any of the key elements and was scored as a 1.
Appendix D

RUBRIC FOR SCENARIOS
RUBRIC FOR SCENARIOS

Each scenario has three sub-questions associated with it, but some of the responses show various parts of inquiry design in the responses, so the first score (5 points) is based on finding the five elements of inquiry ANYWHERE in the three responses. The next two parts are only worth a half point each and either assigns the half point if a reasonable responses was given or zero if no response was given, or the response did not relate.

Response to Part A:
5 pts: Responds yes, no or maybe and offers evidence to back up position including all five elements of inquiry somewhere in the responses and acknowledges it may be teacher and/or student led.

4 pts: Responds yes, no or maybe and offers evidence to back up position including at least four of the five elements of inquiry, and specifically identifies the need for discourse somewhere in the responses.

3 pts: Responds yes, no or maybe and offers evidence to back up position including at least two of the five elements of inquiry, one of which is the need for discourse somewhere in the responses.

2 pts: Responds yes, no or maybe and offers evidence to back up position including at least two of the five elements of inquiry, but does NOT specifically identify the need for discourse somewhere in the responses, OR only mentions need for discussion, but no other elements of inquiry.

1 pt: Responds yes, no or maybe, but offers very little evidence to back up position, and/or makes general reference to only one element of inquiry.

0 pt: Just responds yes, no or maybe with no evidence or the response is too general to code.

Response to Part B: (What do you think happened prior to this lesson). Could have been addressed in section A.
1/2 pt: Response given of possibilities.
0 pt: No response given.
Response to Part C: (What do you think will happen tomorrow in class). Could have been addressed in section A.
1/2 pt: Response given of possibilities.
0 pt: No response given.

Again, the 6-point scale was scaled to a 5-point scale so it could be compared to the other elements of inquiry when specified literally. Since it was possible to receive a point for responding to parts b and c, the scores are altered to reflect a similar pattern as the first open-ended response was scored. For example, in the above example a score of a 3 or 4 indicated a good understanding scored as a 4 meaning they had at least three elements of inquiry identified. A score of a 4 here indicates that they had at least two of the elements identified, but one had to be the need for discourse and they probably also received the addition point for answering section b and c of the question. A score of 2 in the above rubric was re-scored as a 3 that indicates a basic understanding and includes 2 elements on inquiry.

A score of 5 – 6 indicates an excellent understanding of inquiry as defined by NSES and is scored as a 5.
A score of 4 indicates a good understanding of inquiry as defined by NSES and is scored as a 4.
A score of 3 indicates a basic understanding of inquiry as defined by NSES and is scored as a 3.
A score of 1 - 2 indicates very little understanding of inquiry as defined by NSES and scored as a 2.
A score of 0 or ½ indicates no understanding although an attempted response was made, but the response was too general in nature and was re-scored as a 1.
VITA

Kathleen M. Jones
3225 Cold Spring Road
Huntingdon, PA 16652
(814) 641-3654 (office) (717) 571-8669 (cell phone) (814)641-3695 (fax)


1985. Bachelor of Science, Agricultural Education Bachelor of Science, Animal Production The Pennsylvania State University

Other: Pennsylvania Department of Education Professional Certifications:
Agricultural Education K –12, General Science 7-12, Principal K-12; Environment and Ecology K-12
1997 National Writing Project Fellow Writing Instruction Specialist Certificate, Penn State Harrisburg (2001)

Languages: English and Kiswahili

Work Experience:
2005-present Assistant Professor of Education, Juniata College.
2004-2005 Lecturer, Penn State Harrisburg.
2003-2004 Supervisor and Instructor of secondary education students, Penn State University (sabbatical)
1998-2003 Lecturer, Penn State Harrisburg, Capital Area Writing Project (Summers)

Special Honors and Awards:
Exchange teacher to China, People to People Professional Programs (2001).