Teaching Science Through Inquiry in K-5 Classrooms: Analysis of Change in Practice

Joseph Sciulli

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TEACHING SCIENCE THROUGH INQUIRY IN K-5 CLASSROOMS:
ANALYSIS OF CHANGE IN PRACTICE

by

Joseph A. Sciulli

Submitted in partial fulfillment of the requirements
for the degree

Doctor of Education

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School of Education

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by

Joseph A. Sciulli

2004
Abstract

The purpose of this study was to examine the role professional development takes in fostering change in the pedagogical practices of K-5 classroom teachers, specifically in teaching science through inquiry. Michael Fullan’s three elements essential for change: curriculum, instruction, and philosophy, were used as the lens through which to observe and analyze the impact of an intervention for changing teaching practices in K-5 classrooms. The intervention that assisted in creating an environment for change in behaviors was a morphed version of the Exploratorium’s Institute for Inquiry, the ASSET Institute for Inquiry, in Pittsburgh, Pennsylvania. During a three year period 208 teachers attended the five day Institute. It modeled the pedagogy, philosophy and related curriculum strategies indigenous to teaching science through inquiry. Each teacher was sent a questionnaire. The questionnaire was a compilation of Horizon Research, National Science Education Standards, and the National Science Education Inquiry Standard. The analysis of the statistical relationships between the Institute and change in the use of curriculum, instruction, or beliefs in action was done. The results indicate a statistically significant relationship between the Institute for Inquiry and change in teaching practices. There was an increase in the use and implementation of hands-on inquiry-based curricula: STC, FOSS, and INSIGHTS. There was an increase in those instructional strategies and classroom practices supportive of science through inquiry. There was a statistical relationship between the intervention and the NSES indicators of inquiry in practice. Further research was done with regard to teaching experience (i.e., number of years teaching), time interval between completion of the intervention and implementation of the philosophy and strategies indigenous to inquiry, and the relationship a resource
teacher (e.g., teacher teaching teacher) develops with classroom teachers and the practice of teaching science through inquiry. Using the Pearson $r$, the analysis indicates there is no statistically significant relationship how long a teacher has been teaching, the interval of time between intervention and implementation, or the use of a resource teacher. The research concluded with the next research steps: examination of the impact of teaching science through inquiry and student learning.
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First they came for the socialists,
   and I did not speak out
because I was not a socialist.

Then they came for the trade unionists,
   and I did not speak out
because I was not a trade unionist.

Then they came for the Jews,
   and I did not speak out
because I was not a Jew.

Then they came for me,
   and there was no one left
to speak for me.

Pastor Martin Niemöller
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Dedication

To hope...the choice of dreamers.
CHAPTER 1

“A primary responsibility of educators is that they not only be aware of the general principle of the shaping of actual experience by environing conditions, but they also recognize in the concrete what surroundings are conducive to having experiences that lead to growth.”

John Dewey, 1938, p. 35

INTRODUCTION

Overview

The educational system in America is founded in the belief that education is the right of every American and is their pathway to dreams realized (Ravitch, 2001; Rutherford & Ahlgren, 1990). As the nineteenth gave way to the twentieth century, the nation grew in strength and dominance upon the momentum generated by the Industrial Revolution fueled by a work force comprised of immigrants seeking a better life. This better life, the American dream, was seen to be achievable through education. What that education should entail has become the cornerstone of debate that has endured as the nation moved into the twenty-first century.

Central to the debate is which theory of education to promote and what method to use in implementing the theory (Fullan, 2001). An example that illustrates this can be seen with the struggle by the Committee of Ten who advocated a rigorous, teacher-centered academic curriculum geared toward preparing students for higher academia (Presseisen, 1985) against the emergence of a philosophy of education that was child-centered and rooted in experience (Dewey, 1938). The more teacher-centered approach versus the more child-centered approach has contributed to a pendulum effect in American education throughout much of the twentieth century.
Dewey’s philosophy of child-centered instruction, rooted in a pedagogy that was experiential (Dewey, 1938), emerged in the 1930s as the preferred method of instruction for approximately the next twenty-five years (Goodlad, 2002; Presseisen, 1985). The pendulum began to swing back with the publication of Arthur Bestor’s, *Educational Wastelands*, (1953). This text captured the attention of the American people because it gave voice to a nascent thought of Americans concerned about the education of its youth, their future, and the future of the country. The voice grew loud and the debate continued, but with increased vigor, with the launching of Sputnik.

Sputnik marks the beginning of reform, or change, specifically channeled through science education, because the practices of scientists (Layman, 1996) mimic the practices needed to ensure the existence of the grand experiment known as the United States of America (Presseisen, 1985). This journey of reform, sparked by the Russians, began with the passing of the National Defense Education Act (NDEA).

The NDEA set the stage for the evolution of the next wave of reform in American education. This dramatic and exciting journey began with the NDEA, moved to curriculum development in the 1960s, gained momentum with a *Nation at Risk* (Gardner, Larsen, Baker, Campbell, Crosby, & Foster, 1983) and *Science for All Americans* (Rutherford & Ahlgren, 1990) which led to the construction of a framework of reform that was articulated in *Science for All Children* (NSRC, 1997). This framework, though written in 1997, began to coalesce in the late 1980s. The development of the framework established a role science education could play in helping all Americans to be self-actualized citizens. For the purpose of this research, this framework is expressed in the context of a professional development experience called the Institute for Inquiry which
has owes its origins to the Inquiry Institute offered by the Exploratorium in San Francisco, California.

**Historical Perspective**

The release of Third International Math and Science Survey (TIMSS) in 1996, painted an unflattering picture about the teaching for learning cycle that was occurring in classrooms in America (Stigler & Hiebert, 1999) specifically in mathematics and science (Loucks-Horsley, 1999). Coinciding with this third study, the science community had begun activities that developed recommendations which would lead to more effective instruction for improved science education for all children (Lopez & Schulz, 2001). The lessons learned have contributed to the creation of standards and benchmarks. In addition, a vehicle for transferring theory to classroom practice was created with a five pronged model for reforming science education for all children created by the National Science Resources Center (NSRC, 1997).

The elements of the NSRC model are “grounded in principles of pedagogy and organizational development theory” (NSRC, 2000, p. 1). The reform model centers around five essential elements that were derived from the curriculum reform efforts of the 1960s, 1970s, and 1980s (Bybee, 1993; NSRC, 1997). The five essential elements are:

1. Curriculum
2. Professional Development
3. Materials Support
4. Student and Program Assessment
5. Administrative and Community Support
The National Science Resources Center (NSRC) developed these elements into a model for reform that can be visualized in Figure 1 (NSRC, 2003).

Figure 1 National Science Resources Center Theory of Action

Note. From The LASER Center: Leadership and Assistance for Science Education Reform by National Science Resources Center, 2003, Washington, DC. Copyright 2003 by the National Science Resources Center. [Brochure]. Adapted with permission.
The first wave for implementation of the model was in the early 1990s. The use of the NSRC’s model of reform began with the systemic change projects that were in alignment with the Federal Government’s Goals 2000 initiative (NSF 94-73, p.1) known as the Local Systemic Change Projects through Teacher Enhancement: Grades K-8 (LSC). This project invited interested parties to develop a strategic plan using the five elements for structuring their plan. From one of these strategic plans evolved the Allegheny Schools Science Education and Technology (ASSET) project. The birth of this organization, in 1992, and the subsequent LSC grant, became the pathway for the generation and the implementation of the Institute for Inquiry (IFI) which is the intervention in this research study.

ASSET’s LSC was funded through the National Science Foundation (NSF) for five years. The purpose was to assist in the implementation of ASSET’s strategic plan, which is based upon the NSRC reform model, within thirty school districts in southwestern Pennsylvania. One major emphasis of this strategic plan was the incorporation of mechanisms for engaging each teacher in the thirty school districts in intensive professional development, specifically, participating in a minimum of one hundred hours of professional development per elementary school science teacher over the course of the five years (NSF 94-73, p.7).

The original implementation for the one hundred hours of professional development as on-going and in-depth was through teacher training in the implementation of a hands-on, inquiry-based science curriculum. The professional development sessions were aligned with the national standards for science education and for professional development (NRC, 1996). The ASSET model for professional
development has come to mirror the model described in *Designing Professional Development for Teachers of Science and Mathematics* (Loucks-Horsley, Hewson, Love, & Stiles, 1998) as recommended by the Eisenhower National Clearinghouse (1999).

The concept of teachers teaching teachers is central to the professional development plan within ASSET’s strategic plan. The philosophy rooted in the professional development practices are not the usual inoculation, i.e., a one-shot workshop, but are be on-going and in-depth (Loucks-Horsley, Hewson, Love, & Stiles, 1998). Part of this philosophy is supported with the theory and practice embedded in the Concerns-Based Adoption Model (CBAM) by Hord, Rutherford, Huling-Austin, and Hall (1987) and the model for teacher enhancement developed by Danielson and McGreal (2000). The intended use is to enhance professional practice with support through the process with a mentor. For ASSET, this mentor is identified as a Resource Teacher (RT). The RT is a concept that incorporates the philosophy of teachers teaching teachers (Loucks-Horsley et al., 1998) as they move from novice to expert (Costa & Garmston, 1994; Danielson and McGreal, 2000; Hord et al., 1987) in a new pedagogy of teaching science through inquiry (NSRC, 1997).

As the RTs evolved at ASSET, their role generated a need for their own professional development. In order to meet this need, the research teachers attended the Inquiry Institute at the Exploratorium in San Francisco, California. At the Exploratorium, the ASSET resource teachers experienced inquiry-based learning. The learning garnered at the Exploratorium, with modification, became the encouragement and the structure for the first ASSET Institute for Inquiry (IFI) during the summer of 2000. The Exploratorium’s Institute for Inquiry was designed as training for professional
development providers. The ASSET model was modified as vehicle to translate theory into practice in the classroom. The Exploratorium model required the participants to write a plan detailing how they will train their respective professional development providers in inquiry. The ASSET model took this section of the Exploratorium’s model and modified it to accommodate classroom teachers. ASSET used this section of the Institute for Inquiry for the classroom teacher to write a plan for how they will translate the theory and philosophy of inquiry into their respective classrooms.

The morphed IFI is founded in a pedagogical philosophy that believes when learning a new methodology the classroom teacher must be immersed in the process (Loucks-Horsley et al., 1998) and as closely proximate the intended classroom practice (Rhoton & Bowers, 2001). Subsequently, the goals and objectives of the IFI incorporate current research which supports engagement in a teaching for learning cycle, where the learner (i.e., teachers and students) must be actively engaged (Jensen, 1998; Piaget, 1964; Sousa, 2001; Sprenger, 1999) using their hands and their senses to construct their own meaning from their experiences (Brooks & Brooks, 1999; Bybee, 1982; Dewey, 1938). For this researcher, this methodology is the model for teaching science through inquiry.

The concept of teaching science that is experiential based, or inquiry-based, is not a new proposition, actually it was the foundation of John Dewey’s theory for educational change begun in the 1930s (Dewey, 1938; Fullan, 2001). In the 1990s inquiry-based learning gained support when the scientific community (Rutherford & Ahlgren, 1990) and the National Science Resources Center (1997) recommended teaching science using inquiry as the method for meeting the needs expressed by the political and social entities that had raised concerns about the future of America’s workforce (Gardner et al., 1983;
Layman, 1996). With this recommendation for teaching science through inquiry as the
theory for change, the challenge appears in the implementation, or how to translate the
theory to practice.

Statement of the Problem

The aforementioned perspective delineates a belief that science through inquiry be
the primary pedagogical practice with children in K-5 classrooms. Inquiry is the
recommended practice (NRC, 1996; NSRC, 1996; Rutherford & Ahlgren, 1990) rooted in
constructivist classroom pedagogy (Brooks & Brooks, 1999; Bybee, 1993). For this
researcher, inquiry, incorporating constructivist techniques and ideologies, is the
preferred method for teaching science. As agreed in Science for All Americans
(Rutherford & Ahlgren, 1990) the goal is to create a scientific literate America; inquiry is
the vehicle that will deliver. For children in American classrooms to be taught science
through inquiry, the change begins with professional development experiences for
teachers in the philosophy and pedagogy of inquiry science. It must be an in-depth model
mirroring the practice in the classroom. It is the intent of this research to analyze the
impact of teaching science through inquiry in K-5 classrooms.

Significance of the Study

The myriad of reform initiatives relating to theories of change for the American
educational system (Presseisen, 1985) have their impetus from entities in society, the
education profession, and/or political arenas each with an ideological or research-oriented
reason supporting their particular issue for reforming some aspect of the educational
system. With the advent of the 1990s, the three entities have come to articulate similar
concerns about students becoming life-long learners, problem solvers, and collaborative
learners (Layman, 1996). The emphasis has broad and deep implications because it is about systemic reform. To change the system the foundational thinking about the teaching for learning cycle must be addressed (Smith & O’Day, 1990). What is recommended is reforming the pedagogy of science education by mimicking scientists by doing science as inquiry (AAAS, 1990; Layman, 1996).

The challenge that arises from this collective discourse centers on the implementation of this pedagogy for teaching science through inquiry into in K-5 classrooms. The elements recommended by The Glenn Commission Report, *Before It’s too Late* (2000), and the work done by the NSRC (1997) argue for resources and energy to be placed in the classroom. The thinking is these resources would translate into improvement of the teaching for learning cycle. Furthermore, this argument is supported with the research about cognitive development (Bybee, 1993; Sousa, 2001) for teaching science using inquiry.

The beliefs a teacher holds about the teaching for learning process are expressed in their teaching (Hurd, 1993) as it relates to what is important to learn. With the adoption of a new pedagogy, the belief system of teachers becomes the window for reform or change. Professional development is the method that can best serve to enhance the pedagogical practices of classroom teachers (Fullan, 2001; Glenn Commission Report, 2000; Loucks-Horsley et al., 1998; NSRC, 1997) when it offers an opportunity for construction of a different system for believing how to teach, while showing a pedagogical practice to deliver this new or revised philosophy. With inquiry as the theory of change and professional development as the process, the reform of science education has a strong beginning.
Theoretical Framework

Historically, when America articulates a concern it is addressed through its education system. This time the voices coalesce around science education as the major force in achieving this. In doing science as inquiry, the possibility for all Americans to attain their dream becomes a reality (Rutherford & Ahlgren, 1990). The skills that attribute to meaningful participation in America are the same skills needed by the workforce for tomorrow. With the identification of inquiry-based teaching for learning as the theory for change and professional development as the process for implementing the change, the research that unfolds suggests the extent of change in the teaching of science through inquiry in K-5 classrooms occurs when the professional development experience (the process) models the pedagogical practice inherent of inquiry (the theory).

Research Questions

The specific questions guiding this study are:

1. To what extent does the IFI impact the use of science curriculum in the teaching of science through inquiry?
2. To what extent does the IFI impact a change in pedagogy relating to the teaching of science through inquiry in K-5 classrooms?
3. To what extent does the IFI impact a change in beliefs about teaching of science through inquiry as practiced in K-5 classrooms?
4. Is there a relationship between the years of teaching experience and the frequency of use of inquiry in K-5 classrooms?
5. Is there a relationship between the completion of the IFI and use of inquiry in K-5 classrooms?
6. Is there a relationship between the practice of teaching science through inquiry and the frequency of use of a resource teacher?

**Methodology**

For this research, the intervention will be the Institute for Inquiry. There have been eleven Institutes for Inquiry (IFI). Each has been facilitated by the RTs at ASSET Inc. The IFIs are open to teachers from the school districts in the ASSET service area. The Institute for Inquiry is a professional development experience designed to effect change in the teaching of science through inquiry in elementary classroom. The IFI incorporates the philosophy and pedagogy of inquiry relevant to use in elementary classroom. The IFI integrates the constructivist psychology through the strategies used in the delivery of the Institute. These elements come together as the model for how to teach science through inquiry. Throughout the professional development experience the facilitators share with the participants the difference between the roles as the adult learner (andragogy) and the role of the child as a learner (pedagogy).

One unique feature of this Institute is in the application of inquiry into practice. The teachers are required to return to their classroom and conduct their own inquiry into the use of inquiry. They are asked to define a question, establish a procedure, gather data, and return and share their findings. These teachers will be the population that will receive the research tool, the questionnaire.

Horizon Research, Inc. developed a teacher questionnaire for viewing teacher enhancement through local systemic initiatives for the National Science Foundation. This self-reporting questionnaire, with the deletion of a few irrelevant items and with the addition of two components relating to practice, will be the method for data collection to
answer the aforementioned questions. The analysis will flow through three lenses selected to demonstrate change. The questionnaire is designed to self-report practice before and after the intervention, the Institute for Inquiry.

The analysis of change will be viewed through Fullan’s theory (2001) for change. The theory states that for change to occur in practice it must follow three dimensions in order for it to have a chance of affecting an outcome (Fullan, 2001). The three dimensions or components in implementing change are: (1) the use of new curriculum materials, (2) the use of new teaching strategies, and (3) the altering of beliefs about the new curriculum and the related teaching strategies. As outlined in Chapter Three, pre-selected items will be used to determine if there is a perceived change in the practice of teaching science through inquiry relevant to Fullan’s three attributes for change.

To support the perceived change reported by those completing the questionnaire, the second lens is the Science Teaching Standards, A through F, of the National Science Education Standards developed by the National Research Council (1996). They are used as indicators of focus upon change in practice. The participant completing the questionnaire will be asked to rank the emphasis, more or less, of their change in practice in teaching of science in their classrooms.

Corroboration will be garnered as to the use of inquiry in practice through identified items in the questionnaire. The items in the questionnaire relating to the essential features in inquiry classrooms, the third lens, from the *Inquiry and the National Science Education Standards: A Guide for Teaching and Learning* (NRC, 2000). The participant completing the questionnaire will indicate the level of use of these essential features as part of their practice in teaching science through inquiry and the frequency
they use the five essential features. The responses from the items in the questionnaire will be used as indicators of practice in the teaching of science through inquiry in their classrooms.

**Limitations**

- There is variance in the delivery of the intervention due to use of more than one facilitator. The delivery of the IFI requires use of a large, diverse, and fluid faculty.
- The participants could self-select to attend, be directed by their administration, and/or be encouraged by a resource teacher assigned to their district or school.
- The participants could have had prior experience in using inquiry in their practices.
- The questionnaire asks for the respondent to reflect prior to the intervention. On the same questionnaire the respondent is asked to reflect since their participation in the Institute.
- The population was pre-existent.

**Delimitations**

- The questionnaire was designed to include the NSES recommended standards that identify the best practices in teaching science through inquiry.
- The questionnaire was designed to include the NSES components for inquiry in practice.
- The questionnaire was designed around the *Horizon Teacher Enhancement Questionnaire*. 
• The questionnaire will be sent to K-5 teachers who have graduated from the Institute for Inquiry.
Definition of Terms

Andragogy: is the philosophical and methodological practice of teaching adults. It is defined when:

- the learner is involved in the design of their learning,
- the teacher acts as facilitator and rather than didactic approach,
- there is an awareness and accommodation to needs and styles of the learner,
- past experiences are incorporated into the design of the learning,
- the environment is respectful of age and experience of the learner, and
- the experience has a direct relevance to the learner (Brookfield, 1986; Cross, 1981; Knowles, Holton, & Swanson, 1998; Lieb, 1991).

Constructivism: is an approach for the teaching for learning cycle where the teacher creates opportunities for a student to construct their own connections about concepts by challenging their previous understanding as they traverse the path to a new reality of what is happening (Brooks & Brooks, 1999; Martin, 1997).

Curriculum or Curriculum Materials: is defined through three criteria:

- pedagogical appropriateness – inquiry and activity base for the teaching for learning cycle;
- science content – materials are scientifically accurate and developmentally appropriate;
- presentation and format of the information – clarity of the information and how it is presented in the written materials (Fullan, 2001).

Inquiry: is an approach to the teaching for learning cycle which involves mirroring real science as the world is explored through the generation of questions which lead to
discoveries which generate evidence that is tested against previous knowing (Exploratorium Institute for Inquiry, 1999).

**Pedagogy:** is the philosophical and methodological practice of teaching children (Knowles, Holton, & Swanson, 1998).

**Professional Development:** is “a planned, collaborative, educational process of continuous improvement for teachers that helps them do five things:

1. Deepen their knowledge of the subject(s) they are teaching;
2. Sharpen their teaching skills in the classroom;
3. Keep up with developments in their fields, and in education in generally;
4. Generate and contribute new knowledge to the profession; and
5. Increase their ability to monitor students’ work, so they can provide constructive feedback to students and appropriately redirect their own teaching” (The Glenn Commission Report, 2000, p.32).

**Reform:** is to bring about a change in belief about the pedagogy of teaching science through inquiry (Bybee, 1993, Fullan 2001; Hurd, 1993).

**Resource Teacher:** is a K-5 classroom teacher who has demonstrated initiative in assisting teachers as a mentor or coach in supporting change in practices in classrooms relating to the teaching of science using inquiry-based instruction (Costa & Garmston, 1994; Danielson & McGreal, 2000; NRC, 1996, 2001).

**Systemic Reform:** is an attempt at aligning the curriculum with student assessment and in-depth teacher preparation, into a coherent and comprehensive effort that increases opportunities for all students to learn (Smith & O’Day, 1990; Vinovskis, 1996).
Summary

The framework for the system for educating Americans is designed to ensure the survival of the country and to be the vehicle for fulfilling dreams for its citizens. When documents such as *A Nation at Risk* report the state of the nation and its troublesome future, or the report that followed from the TIMSS findings about the lack of learning the future workforce has achieved, fault is laid at the feet of the education system, while simultaneously becoming the vehicle for reform.

In the 1990s, the driving voices have coalesced around the same set of issues to address. The recommended strategy that has evolved is centered on the practices of real science defined as the use of the pedagogy of inquiry in teaching science in elementary classrooms. To incorporate the use of inquiry into the on-going pedagogical practices of elementary teachers requires a change in their beliefs about what is important to teach. The existing channel through which teachers have an opportunity to have their beliefs challenged is through professional development defined as on-going and in-depth. This type of professional development scaffolds opportunities that nurture the examination of a belief with the possible outcome of an altering of the belief which impacts change. The theory inherent to this research lies with the conviction that professional development can be structured to deliver a philosophy and its pedagogy which generate opportunities for change in belief about practice to occur.
CHAPTER 2

“When you work to your full capacity, you can hope to attain the knowledge and skills that will enable you to create your future and control your destiny. If you do not, you will have your future thrust upon you by others.”
A Nation at Risk, 1983, p.35

REVIEW OF THE LITERATURE

Introduction

The evolution of the system of education in America, beginning with the common school movement (Webb, Metha, & Jordan, 2000), has had an arduous history (Gutek, 2000). From this early start, the premise has been, and to some extent is still present, that the American system of public education is free and is a vehicle for opportunity. This opportunity is grounded in the belief that the American educational system “could enable any youngster to rise above the most humble of origins and make good on the nation’s promise of equal opportunity for all” (Ravitch, 2000, p. 19).

From the beginning, the struggle as to how this opportunity would be delivered, has centered on who should be educated and what that education should entail (Resnick, 1987). The arguments advance primarily from the perspectives of the will of the society, of the behavior inherent in the political process, and of the education profession itself (Astuto, Clark, Read, McGree, & Fernandez, 1994; Bybee, 1993). Each has used its influence in an attempt to answer who should be educated and/or what that education should encompass (Presseisen, 1985).

There is a current reform underway that stresses the teaching of science through inquiry with the use of quality, hands-on materials (National Research Council, 1996; National Research Council, 2000). Furthermore, the translation of these suggestions into
practice resides in the recommendation that pertain to teachers receiving in-depth professional development (Loucks-Horsley, Hewson, Love, & Stiles, 1998; Loucks-Horsley, Love, Stiles, Mundry, & Hewson, 2003). The current reform in science education, wherein this research is rooted, requires a change in the conventional methods for teaching science. A change to teaching of science through inquiry is desirable because it meets the needs of American citizens as participants in a global society. To make Americans part of this global society, the educational system is being called upon to implement these suggestions into the rhythm of the classroom.

This time the voice of society, the political process, and the educational profession merge in belief about making Americans life-long learners, problem solvers, and informed citizens. The recommendation to meet these needs is to use inquiry. The use of inquiry begins with the teacher in the classroom. Teachers will be pivotal in using inquiry as the vehicle for teaching science. The intent of this research is to examine the effect professional development exerts in translating this theory to practice. What unfolds in this dissertation is an analysis of the effect professional development has upon the translation of the theory and philosophy of inquiry into the pedagogical practices in K-5 classrooms.

**Perspective from History**

At the crossroads of the 20th Century, the United States emerged as a major influence in the world, replete with issues that affected the evolving America. Some of these issues were brought about by the erosion of the agrarian traditions as the “industrialization, urbanization, and immigration” (Reese, 2000, p.27) transformed the nation. With this transformation, there emerged a vehicle that was used to address the
pressing issues of the nation. What emerged and became embedded in the culture of America is the practice of using the educational system to meet the needs of the nation as it grows, develops, and evolves (Ravitch, 2000; Spring, 2001). At the core of this practice was the debate about who should be educated and what that education should be. The debate during the 19th century was framed around the use of the educational system as the vehicle for change, or reform. Central to the discussion was curriculum and pedagogy. It begins with the Committee of Ten and was challenged by the progressives and ends with Sputnik, albeit with a decided twist that requires reframing the argument, but with a broader, deeper perspective.

**The Argument**

By the late nineteenth century, almost every area of the nation had an elementary school but there were few high schools (Ravitch, 2000). Those that existed had as their main purpose the assimilation of immigrants and the offering of technical training (Ravitch, 2000; Webb, Metha, & Jordan, 2000). In 1892, a reform effort, The Committee of Ten, was established by the National Education Association in an effort to standardize curriculum for colleges and challenge how high schools should be used (Webb, Metha, & Jordan, 2000). Their curriculum was academic in nature and in scope and sequence. The intent was for secondary education to react by establishing a curriculum for their students that supported pursuit of higher academia. The Committee of Ten did not achieve this (Presseisen, 1985).

The academic curriculum developed by the Committee of Ten was dismissed by the next reform movement in education (Ravitch, 2000; Webb, Metha, & Jordan, 2000). This movement was a sharp contrast to earlier goals. It put forth a new, differentiated
approach (Ravitch, 2000) which believed “that learning should emanate from the interests and needs of the child and that most appropriate curriculum was activity-based that encouraged children to express themselves freely and creatively” (Webb, Metha, & Jordan, 2000, p. 209). This philosophy of the differentiated curriculum was at the heart of progressive education (Gutek, 2000) with roots as far back as Jean Jacques Rousseau (1762/1969). Progressive education was about wrapping the curriculum around the learner (Dewey, 1938).

No person better articulated the philosophy of progressive education than John Dewey (Norlander-Case, Reagan, & Case, 1999). Dewey saw the main purpose of schools was in preparing the youth for their future as responsible members of society (Dewey, 1938). To achieve this, Dewey believed in the use of the method of scientific inquiry, where a solving of one problem raises curiosity in a child which leads to more intellectual involvement (Dewey, 1938; Dow, 1999). This scientific method for inquiry is a methodology that mirrors Dewey’s philosophy of child-centered learning, channeled through experience, as it relates to the learner (Dewey, 1938). Central to this approach to learning was, as an outcome, the promotion of the growth of the individual and in the preparation of “the child for full participation in our democratic society” (Dewey, 1938; Webb, Metha, & Jordan, 2000, p. 209).

By the 1950s, progressive education had become the pedestal of theory in practice in the nation’s schools. The progressive’s theory had remained unchallenged because the administrative reformers from the early part of the century had maneuvered the American psyche to believe that education is best left to the experts (Mondale & Patton, 2001). But, as the 1950s unfolded, the critics began to increase in voice, expressing their
concerns. No one critic was more expressive than Arthur Bestor in his attack on education in his book *Educational Wastelands*, which criticized the curriculum for being watered down leaving people not knowing how to think (Dow, 1999). There was a movement for a return to a more conservative approach to teaching and learning (Gutek, 2000). This approach, sometimes referred to as the traditional method for instruction, would have been the next significant wave of reform if it were not for the Soviets and *Sputnik*.

On October 4, 1957, with the Soviet’s launching of *Sputnik*, the first satellite into space, “convinced many Americans that the USSR had achieved scientific superiority over the United States” (Dow, 1999, p. 1). The school system became the target for why this was happening and yet, again, the school system would become the vehicle for rectification. What ensued was a melee of ideas as to the better approach to teaching for learning.

**Precursors to Science Reform**

The voice of the American people, after the Russians successfully launched *Sputnik*, hit a crescendo that resonated into reforms that focused on math, foreign languages, and science. It began with the passage of the National Defense Education Act (NDEA) in 1958. The name, National Defense Education Act, defined the level of concern of the Nation and it established the avenue for reform. Furthermore, the NDEA was historical in the amount of federal funding and its reach into the curricular heart of American education (Presseisen, 1985).

One reaction to the launching of *Sputnik* generated reform efforts about teaching and learning specifically targeted toward science curriculum. Residuals from these
efforts continue to influence science education in the 21st century, particularly from the legacy of NDEA and the subsequent focus on curriculum (Presseisen, 1985) with a spotlight on science. The reactions which followed NDEA spawned new curriculum materials and a rethinking of the accompanying pedagogy. Even though the rethinking about how children learn, knowing that children learn best when actively involved (Dewey, 1938; Piaget, 1964; Rousseau, 1762/1969), the debate continued over which pedagogy, traditional or child-centered, would best address the concerns expressed in the NDEA legislation.

One direction that was pursued involved the development of curriculum in the 1950s and 1960s which put the child-centered theory into practice (Lopez & Schultz, 2001). The significance of these attempts to incorporate inquiry-based pedagogy is seen best through a lens of lessons learned, more than in their place in the continuum of American education. It is in retrospect that common elements from the curricula from the 50s and 60s emerged to impact the teaching of science through inquiry as we move into the 21st century.

For context, the history of reform in science education is better developed through an overview of three of the more widely used child-centered curricula of the 50s and 60s. These curricula are included to demonstrate the legacy these curricula advocate to current science education reform, more than as a deliberate focus on the individual curricula (DeBoer, 1991; Dow, 1999; NSRC, 1997). The three more popular curricula were Elementary Science Study (ESS), Science - A Process Approach (S-APA), and the Science Curriculum Improvement Study (SCIS) (DeBoer, 1991).
ESS, S-APA, and SCIS were rooted in the philosophy of experiential, or discovery, learning which involves the whole of the child (DeBoer, 1991). The curricula were content oriented, incorporating the use of appropriate materials for manipulation by the learner as a means for discovering (i.e., learning) the concepts (Karplus & Their, 1967; Sanderson & Kratochvil, 1971). It was in the manipulation of the materials where the active engagement of the learner made the learning relevant (Bybee, 1982; Piaget, 1970; Piaget, 1964). Eventually, each of these proved the student-centered approach for learning was the plus (Lopez & Shultz, 2001). These curricula have faded from use; however, their experience-centered pedagogy is the part that their legacy reinforces.

Building upon lessons learned through the use of ESS, S-APA, and SCIS curricula, the National Science Foundation (NSF), in the 1980s, through the National Science Resources Center (NSRC) began funding the development of curriculum materials for K-6 students. What evolved are three inquiry-based hands-on curricula: Full Option Science System (FOSS), Science and Technology for Children (STC), and Insights. It is with the development of these three curricula and research by National Science Teachers Association (NSTA) and the NSRC that a model for the next wave of reform emerged.

The Next Wave of Reform

The NSTA conducted a survey of the nation to locate districts still using the aforementioned curriculum materials (Penick, 1983). The information revealed from the survey identified a handful of districts that had sustained their exemplary, kit-based programs (Lopez & Schultz, 2001). The information gathered from the identified districts and the subsequent work with Doug Lapp, an architect of one of the identified
districts, and the NSRC, found five elements common among the districts (Lopez & Schultz, 2001; NSRC, 1997). The five elements in common are:

1. Selection of the best materials available to best facilitate conceptual development was needed.
2. A science materials support center because requiring teacher to amass the materials needed to teach inquiry science was unrealistic.
3. Sustained ongoing professional development supported the delivery of the curriculum and the subsequent professional development needs of the teacher.
4. Assessment that supported the inquiry method was required.
5. Sustained administrative support helped ease the transition for the teaching and learning process within the learning community.

At the time this information (which articulates a way to sustain an inquiry-based science curriculum) was being collected, the authority from the political arena and the science community converged. The groups took this information, constructed a model, and used the model to initiate reform for education, specifically science. This reform was different.

With the release in 1983 of *A Nation at Risk* (Gardner et al., 1983) and the release of *Project 2061* in 1989 by the American Association for the Advancement of Science (AAAS), momentum for curriculum renewal would be the generator for reform efforts. The discourse brought about through the publication of these two documents, with the former generating public awareness and the later articulating the need for a scientific
literate citizenry, helped to ignite and sustain a discussion which became the framework for science reform in the 1990s.

The release of *A Nation at Risk* established parameters for a discussion about the condition of education in America, specific to the current and future needs of the nation’s citizens (Gardner et al., 1983). The text ends with a list of five recommendations offered to the American people for their consideration. These five recommendations (See Appendix D) frame the state of education in America and what can be done about it, with a specific mention of science education. The significance of these five recommendations is underscored with an examination of a set of indicators of risk used to demonstrate the condition of the American education system (Gardner et al., 1983).

As set forth in the report, these indicators were derived from “amply documented testimony” (Gardner, et. al., 1983, pp. 8-9) garnered by the National Commission on Excellence in Education. The testimony highlighted the indicators of risk: low comparison on international level of other industrialized nations, rise in functioning illiteracy in America, decline in high school achievement, decline in College Board’s Scholastic Aptitude Tests, increase in remedial math courses at the college level, spending of millions by business and the military on remedial education, and “the steady decline in science achievement scores of U.S. 17-year-olds as measured by the national assessment of science in 1969, 1973, and 1977” (Gardner, et. al., 1983, p. 9).

Then in 1985, intentionally coinciding with the appearance of Halley’s Comet, scientists and educators converge under the auspices of the AAAS to begin an ambitious project, *Project 2061*, to help the American education system develop science literate citizens by the year 2061, when Halley’s Comet will return. With the establishment of a
goal that envisions all students becoming well educated in science, mathematics, and technology (Rutherford & Ahlgren, 1990), the meeting created a set of tools to assist in designing curriculum that supports success for all American students. In two volumes, *Science for All Americans* (Rutherford & Ahlgren, 1990) and *Benchmarks for Science Literacy* (AAAS, 1993) an outline of what students should know and be able to do as they progress through their elementary and secondary education (AAAS, 1993) was detailed. The collective thinking of the members of the scientific and educational communities who assisted in these collaborative works succeeded in defining the nature and purpose for the next reform effort. The pathway for the reform movement of the 1990s was around the writing of standards across the curriculum spectrum, with science being the first to pass the scrutiny of the American public (National Science Resources Center, 1997; Bybee, 1993).

**Framework for Science Reform**

In the late 1980s and the early 1990s, the organizations (e.g., National Council for Teachers of Mathematics, National Council of Teachers of English, and National Council for the Social Studies) that are representative of curriculum areas began to contribute to the argument for reform by writing national standards specific to their subject. One such organization, the National Research Council (NRC), reacting to the goals established by the nation’s governors at the Education Summit in 1989, convened by President George Bush (Hoffman & Broder, 1989), wrote the National Science Education Standards (NSES). The NSES, which had “established as a goal that all students should achieve scientific literacy” (NRC, 1996, p. ix), wrote their standards to be reflective of the needs and interests of the Nation.
Theoretical Frame

Overview

The path to the aforementioned standards begs systemic reform. Systemic reform, by operation, is a change in the beliefs of teachers about how students learn coupled with an appreciation of methods that are more conducive for teaching to this philosophy of learning (Fullan, 2001; Hall & Hord, 1984, 2001; Smith & O’Day, 1990), thus influencing the educational system. The NRC (2001, 2000, 1996), the NSRC (2000, 1997), and the AAAS (1990) recommend the infusion of inquiry in the classroom practice to achieve this systemic reform.

For this research, a model for change is presented (See Figure 2). This model is built from the change theory of implementation by Michael Fullan (2001) where he lists three components to achieve a change in practice. They are materials, teaching approaches, and alteration of beliefs (Fullan, 2001). Materials are the instructional resources such as curriculum materials. Teaching approaches are new strategies or activities associated with the curriculum. An alteration of beliefs is required when the teacher incorporates the curriculum and materials into the classroom routine. This last component occurs when the curriculum is a shift from a held belief about how the teaching for learning cycle unfolds in the classroom.

In addition, the model presented by this researcher is influenced by the Zone of Optimal Learning model developed by Stephen J. Farenga, Beverly A. Joyce, and Daniel Ness (2002). Their model is a strategy for aligning curriculum, instruction, and assessment. It is in the interplay of these three elements that an environment that is optimal for learning can occur (Farenga, Joyce, & Ness, 2002). Their model is a theory-
based strategy to create this optimal learning that assists the learner in achieving a strong knowledge base in science. The model presented by Farenga, Joyce, and Ness discusses the three as separate entities and how their model integrates those (2002). It is in the overlapping areas, the juncture of integration that their model of reform occurs.

Figure 2 Optimized Learning Opportunity

The model presented by this researcher builds the concepts inherent in the interplay of the three entities infused through a theory and philosophy of inquiry. This is accomplished through interplay of the NSRC’s (1997) five elements for reform translated through the three components for change in practice offered by Fullan (2001). As
Fullan’s three components affect the implementation of change, the use of inquiry brings its theory and philosophy into practice requiring these components to generate learning opportunities reflective of deep understanding, hence, changing the learning environment. It is at these interchanges that the practice of inquiry and the elements of change foster opportunities for optimized learning to occur. The model developed and presented has a title that characterizes the intent of the change and the reform, Optimized Learning Opportunity, OLO. The circles represent the three elements for implementation overlapping the element of inquiry. It is opportunities for change which support new opportunities for learning science are generated. What follows is a detailed description of the three concentric circles of the OLO model and the interaction caused by the overlaps.

The upper left circle is curriculum. Curriculum is operational when the cognitive, social, and emotional aspects of learning are congruent with the learning environment (Brooks & Brooks, 1999). Part of the congruence consists in the knowledge and skills residing in the teaching for learning cycle (Pellegrino, Chudowsky, & Glaser, 2001; Wiggins & McTighe, 1998). This is developed systematically as “a specific plan with identified lessons in an appropriate form and sequence for directing teaching” (Wiggins & McTighe, 1998, p. 4). Furthermore, “[t]he best curriculums . . . are written from the learner’s point of view . . . [specifying] what the learner will do, not just what the teacher will do” (Wiggins & McTighe, 1998, p. 4).

The upper right circle is instruction. This instruction is significant when it is aligned with the developmental needs of the learner (Bybee & Sund, 1982; Piaget, 1964, 1970). When instruction utilizes appropriate curriculum and its subsequent materials, a learning opportunity is created (Bybee & Sund, 1982; Dewey, 1938). This learning
incorporates prior knowledge of the learner allowing for an opportunity for dissonance in what they know with what they have recently discovered. It is at this juncture that learning happens (Piaget, 1964, 1970). For the teacher to assist the learner in arriving at this juncture, materials as well as a theory about the teaching for learning cycle are critical (Lowery, 1998; NSRC, 1997).

The bottom circle is philosophy. It is here the interplay of instruction with curriculum is rooted. What teachers believe to be important becomes their philosophy in action (Heckman, Confer, & Hakim, 1994; Hurd, 1993). The use of curriculum that is reflective of a new methodology is one of the first steps needed for reform. Coupled with this curriculum are materials designed to construct experiences which foster learning of new concepts (NRC, 2000). Both the curriculum and materials require the teacher to develop new strategies (Fullan, 2001). The implementation requires a change in belief (Fullan, 2001; Heckman, Confer, & Hakim, 1994; Hurd, 1993).

The intersection where philosophy and instruction, instruction and philosophy, and curriculum and instruction cross generates learning opportunities that enhance the teaching for learning cycle. What borders these intersections, in the inner part of the circles, is inquiry. Inquiry intensifies the intersections. When the three outside forces of curriculum, instruction, and philosophy are pressed against the inside force of inquiry change can happen. The pressure brought from these two forces creates new opportunities. This change is optimized learning opportunity (OLO).
Theory Construction

For the ideas behind the OLO model to impact the system, teachers must adopt the inquiry-based curriculum utilizing hands-on materials, (i.e., the C). The use of this curriculum will require different instructional strategies, (i.e., the I) that come about through a shift in the beliefs held by teachers about how children learn, (i.e., the P). Inquiry is the tool to which the three components can effect change in the teaching of science through inquiry in elementary science classrooms.

The first component of this theory is inquiry. Definitions are offered to establish inquiry in its operations, what it looks like when it is happening. Next, there is offered the cognition behind inquiry. Constructivism is the thinking behind the operation of inquiry in practice for teachers and learners. Within this part of the theoretical argument, support is garnered from the work of Piaget, Vygotsky, and Ausubel.

Cognition is a good argument for the teaching of science through inquiry. But when it is backed by the work uncovered through brain research, it becomes incredibly powerful. Brain research supports cognition, (i.e., constructivism), in using the technology of medical science. The lens through which this research is viewed is from the perspective of the classroom and its subsequent implications about teaching for learning.

Professional development is detailed. This is the path for sharing of new ideas about teaching. Additionally, if incorporated in recommended way, it is a means to an end. It affords professionals the opportunity to engage in a collegial environment about the craft of teaching. It engages the teacher in meaningful discourse relating to reform
and the process associated with the reform. This is the event through which the research is based.

**Inquiry**

The goal recommended in the National Science Education Standards (See Appendix A) is to move away from the traditional approaches for teaching (e.g., lecture, text books, and/or multiple subjects) and move toward teaching science through inquiry (e.g., hands-on, child-centered, in-depth subject). The recommendations of the National Research Council, combined with the curriculum efforts and model of reform of the National Science Resources Center, coalesce in the process and philosophy of inquiry as a means for achieving science literacy and attaining a National goal of “a high level of shared education . . . essential to a free, democratic society and to the fostering of a common culture, especially in a country that prides itself on pluralism and individual freedom” (Gardner, et. al., 1983, p. 7).

Inquiry replicates the way students, (Dewy, 1938; Piaget, 1964; Rousseau, 1969/1762; Sousa, 2001) and scientists model each other (Alberts, 2000; Llewellyn, 2002; NRC, 1996, 2000). An outcome stated in *A Nation at Risk, Goals 2000*, and *Educate America Act* is to make for life-long learners, which is the practice of incorporating the child with the adult. Inquiry is perceived as an ideal practice for achieving this goal (NRC, 2000; Schwab, 1962).

What is this process of inquiry? It has been around since the time of the Greeks. Socrates used the process of inquiry when teaching. His process, known as the Socratic Method, had philosophical underpinnings about the enculturation of the citizens as it related to their role in the state. Socrates believed the goal of education was to develop
knowledge in the citizen that was acquired as their reasoning potential developed (Webb, Metha, & Jordan, 2003). This process is understood by this researcher as meaning a practice that is developmentally appropriate. Socrates’ philosophy can be used as a mirror to the goal of America for fostering informed citizens.

Inquiry was such a strong belief of Rousseau that he defined inquiry in the introductory chapters of his fictional account, Émile (1969/1762). Rousseau’s philosophy is applied as he recounts the struggle of Émile and his decision to marry. Émile’s choice is counterintuitive to what he has come to know about himself. His tutor could use lecture to deliver this message, but the tutor chooses to use this as an opportunity for self-discovery, through the use of inquiry method. This method of inquiry requires the tutor to pose questions to which Émile must reflect, explore and apply his thinking as he proceeds. From the subsequent discourse, Émile determines his current choice for a wife is not inline with what he knows himself to be. In the future, Émile uses this knowledge as he explores similar decisions, thus finding a mate that is compatible.

In the 20th century the question about which methodology to use to teach had a strong stimulus from John Dewey and his immense influence on modern education. Pivotal to his influence was the conviction that inquiry replicates learning that is child-centered as it builds upon the child’s natural sense of wonder or curiosity (DeBoer, 1991; Dewey, 1938).

The debates about the state of education in America continued into the 1980s with inquiry precipitating from the discussion as the vehicle for addressing the aforementioned needs. Central to the effect of this dialogue was the publication of A Nation at Risk (Gardner, et. al., 1983). This single document stirred the conscious of the American
people about education and America’s global position and national security. The debate that ensued looked for ways to address the needs and concerns of the Nation. One such way is identified in the use of inquiry. Since then, inquiry has been defined to reflect practice, process, and/or methodology, sometimes categorically, and sometimes indistinguishable from each other.

An examination of the process of inquiry can be explored through a survey of definitions. According to the National Research Council (1996),

Inquiry is a set of interrelated processes by which scientists and students pose questions about the natural world and investigate phenomena; in doing so, students acquire knowledge and develop a rich understanding of concepts, principles, models, and theories. Inquiry is a critical component of a science program at all grade levels and in every domain of science, and designers of curricula and programs must be sure that the approach to content, as well as the teaching and assessment strategies, reflect the acquisition of scientific understanding through inquiry. Students then will learn science in a way that reflects how science actually works (p. 214).

This definition was expanded upon when the National Research Council published Inquiry and the National Science Education Standards (2000) where Bruce Alberts (2000) says, “Students [that] need to learn the principles and concepts of science, acquire the reasoning and procedural skills of scientists, and understand the nature of science as a particular form of human endeavor” (p. xiii). Alberts (2000) continues to define inquiry through support of “studies show . . . students are much more likely to understand and retain the concepts that they have learned this way” (p. xiii).
The Exploratorium, as a center for professional development, operating with a NSF grant for inquiry-based learning, assembled a definition about inquiry that has depth and breadth. It is included in its entirety because their model of professional development was subsequently morphed to ASSET’s Institute for Inquiry (IFI) as the intervention for this research. So, with that established, *Foundations*’ (Exploratorium Institute for Inquiry, 1999) monograph delineates:

**Inquiry is an approach to learning** that involves a process of exploring the natural world or material world, and that leads to asking questions, making discoveries, and rigorously testing those discoveries in the search for new understanding. Inquiry, as it relates to science education, should mirror as closely as possible the enterprise of doing real science.

**The inquiry process** is driven by one’s own curiosity, wonder, interest, or passion to understand an observation or solve a problem.

**The process begins** when the learner notices something that intrigues, surprises, or stimulates a question – something that is new, or something that may not make sense in relationship to the learner’s previous experience or current understanding.

**The next step** is to take action – through continued observing, raising questions, making predictions, testing hypotheses, and creating theories and conceptual models.

**The learner must find** his or her own pathway through this process. It is rarely a linear progression, but rather more of a back-and-forth, or cyclical, series of events.
As the process unfolds, more observations and questions emerge, giving occasions for deeper interaction with the phenomena – and greater potential for further development of understanding.

Along the way, the inquirer collects and records data, makes representations of results and explanations, and draws upon other resources such as books, videos, and the expertise or insights of others.

Making meaning from the experience requires reflection, conversations, comparisons of findings with others, interpretation of data and observations, and the application of new conceptions to other contexts. All of this serves to help the learner construct a new mental framework of the world (p.2).

Constructivism

Science builds on the natural curiosity of children (Dewey, 1938; Doris, 1991; Llewellyn, 2002). How to build upon this curiosity is the challenge. At the heart of the teaching for learning cycle is a search for students’ understanding of concepts. The teacher must probe with questions, alternative information, directed research, and engage the learner in inquiry where there will be an opportunity to challenge held beliefs (Brooks & Brooks, 1999).

The use of curriculum that is hands-on and inquiry-based is not enough. A role for professional development becomes significant, because it is in professional development that the answers to the questions about facilitating real learning can be explored. Within the model of professional development outlined in the LSC for ASSET, teachers were required to have one hundred hours of professional development. As the teachers began their engagement with this model, they began to move along the teacher
continuum from novice to expert in the use of the modules (Danielson, 2000; NSRC, 1997). As they moved along the continuum, there was collective voice that asked for more. What that more was, was unclear.

In addressing the needs of the teachers, ASSET morphed the Exploratorium’s Inquiry Institute. This new structure was designed to address the needs of the practitioner. One big idea that was central to the ASSET Institute for Inquiry was around what is learning.

John Dewey had a theory that learning grows from the natural curiosity of the learner. This theory had support from the educational community because, one can surmise, rang true to educators and others in the learning community. The challenge from the traditional side of the argument was a limited argument because of the lack of research.

At the time of Dewey, the French psychologist, Jean Piaget was conducting research around the learning process. Piaget was a biologist at the beginning of his career. This gives context for the organic view that learning is a building process (Bybee & Sund, 1982; Vygotsky, 1978). It can be built alone as in being left to one’s own devises or it can have a path that is facilitated by a caring and nurturing teacher. The path taken and the subsequent learning about how to learn that evolves, is ominous against the goal for reform in making life long learners.

Piaget’s work is central to understanding constructivism (Brooks & Brooks, 1999; Llewellyn, 2002). Piaget’s theory has an organic structure that pulsates from the three concepts of cognitive structure, cognitive functions, and cognitive content. An operational definition is essential before the process of learning can be explained.
Cognitive structures are the stages of development. Piaget theorized that learning required experiences upon which to build the next experience. This building was tied to organic development. There needed to be a certain physical maturation that accompanied cognitive maturation. As each emerged, they built with the prior to move to the next.

Cognitive functioning is what the person does as they move through their stages of development. As the learner moves through their stages of growth, they organize and adapt (Vygotsky, 1978). The organization is the behavior that requires action (Piaget, 1970). The learner develops a system for action and integrates either a mental or physical action that is a demonstration of a higher order of thought. An example would be using the eyes to look around the room for a desired object. Once it has been identified there is an integration of the hands and the eyes to reach for the desired object (Bybee & Sund, 1982). It is in this integration of thought and action that the cognitive structure continues to move across time and development.

This continuity across time and development happens through adaptation. Adaptation is an adjustment to the world around it with experience having a direct effect the stage of development (Bybee & Sund, 1982). Adaptation is a combination of assimilation and accommodation. Assimilation is an interpretation by the learner about their world so it makes sense. If the making sense is built upon faulty sensory input, a misconception develops (Llewellyn, 2002).

Accommodation happens when the learner needs to change to fit the new information or experience. As the learner attempts to accommodate the new information or experience, a situation can occur where the learner enters a state of disequilibrium.
This state of disequilibrium produces conflict that requires examination and a restructuring of thought because the learner always wants to return to equilibrium. It is at this moment when a challenge to a held thought, or belief, encounters a different thought, or belief, that learning occurs (Bybee & Sund, 1982). In brief, the learner accommodates their thinking by adapting to it, rejecting it, or using it to strengthen their knowing (Llewellyn, 2002).

Cognitive content refers to the observable behaviors. This is the distinguishable elements that identify intelligence. It is here that Piaget’s theory of intelligence grows (Bybee & Sund, 1982; Piaget, 1964). It is in the study of intelligence and how the learner garners knowledge from his environment that support for inquiry resides.

As a case for research-based, inquiry-based, child-centered curriculum, Piaget’s theory that has application to the teaching for learning cycle can reflect:

1. Understanding that students will have different explanations of reality at different times in their life.
2. Recognition of the stages of cognitive development in the formulation of lessons, units, and curricula.
3. Attempts to facilitate development through situations that engage learners and require cognitive adaptation (disequilibrium versus equilibrium).
4. Use of methods and materials that are activity based requiring hands-on and minds-on involvement (Bybee & Sund, 1982; Vygotsky, 1978).

Piaget’s theory is the basis for constructivism. This approach to the learning cycle is in contrast to the traditional methods for instruction in American schools. It is in direct conflict with those students who are successful more because of the covering of
Constructivist teaching helps learners to internalize information. The constructivist teacher offers opportunities for moments of disequilibrium and supports emergence of new thinking through a nurturing interaction between the learning, the learner, and the teacher. The use of quality manipulative materials is the impetus for creating these opportunities.

Furthermore, the manipulation of materials is one method to encounter our world and seek an understanding of reality. When the materials offer discrepant data, the learner either interprets what is seen, making it conform to the present reality, or a new reality is generated which better explains what has been perceived (Brooks & Brooks, 1999; Bybee & Sund, 1982). Learning is not a stagnant process but one that is fluid and in a constant state of change. The exchange of ideas brought about through the curriculum requiring a hands-on approach as it engages the mind of the learner is critical to this learning process. It is where “*children solve practical tasks with the help of their speech, as well as their eyes and hands*” (Vygotsky, 1978, p. 26).

Supportive of this teaching for learning is the work done in the medical profession about how the brain learns. When there is a merge between what brain research has learned with cognitive psychology, the understanding of learning takes a deeper, broader, and more significant perspective. What is next is an overview of brain research as it applies to the learning processes.

**Brain Research**

Supporting the theory of constructivism is the work completed in the past twenty years on the working of the brain. It is with the work done in the medical field that much
of what we know about how the brain functions has been discovered. The work of the researchers lends support to the work of cognitive psychologists and educational theorists.

For most teachers, their training has focused “on the behaviorist model which tries to explain what is happening inside the brain (following a stimulus) by observing outside behavior (the response)” (Sousa, 2001, p. 1). There was a limitation to this work because it dealt with the brain which could not be seen and the response was the physical interpretation by the respondent (Jensen, 1998; Sousa, 2001). The limitation was in the accurate interpretation of the information.

The use of computerized technology has contributed to the study of the brain. Being able to take a snapshot of the physiological reaction of the brain to an event has contributed to the understanding of process. In addition, the chemical, or physiological reaction, can be traced to the end points, or storage areas of the brain. Indication of multiple storage points leads to an understanding that the brain has highly developed structures for storage, and subsequently for retrieval (Jensen, 1998; Sousa, 2001; Sprenge, 1999).

The implications for teaching are especially significant when viewed as support for the use of inquiry. The belief is inquiry is an experience that replicates the natural curiosity of a learner. This is supported by the body of knowledge gained from the study of the brain validates the practice of inquiry in the classroom. In the forefront of this research is the research which states we cannot teach the brain to think, we can only help it develop efficient and effective ways to store and retrieve information (Sousa, 2001;
Through the use of hands-on quality materials and a philosophy of inquiry, learners can develop these effective and efficient pathways. For the brain to begin the transfer of information into memory for later retrieval and subsequent manipulation for expressions of understanding and ideas there are three conditions that must be met. First, the main reason the brain exists is to keep the body alive. If the brain feels threatened it will not begin the process of learning until it feels safe. This is a critical revelation and supports the notion that has been stressed about the environment of an inquiry-based classroom. This is a classroom where there is freedom of movement and freedom of physical exploration (hands-on) and mental exploration (minds-on) during the interaction with the materials designed to construct opportunities for learning.

Second, the brain must feel a sense of purpose and a knowing of success about that which it is engaged (Dewey, 1938; Piaget, 1964; Sousa, 2001). The role of the teacher and the role of materials are critical at this juncture in the teaching for learning process. When using the National Science Resources Center recommended curricula, the field testing prior to release, reflects sound pedagogical practice (NRC, 1996; NSRC, 1997). As the learner is engaged in the activity it is crucial for the teacher, or facilitator, to know when to ask questions, when to offer information, and when to direct the learner to further resources (Llewellyn, 2002; Marek & Cavallo, 1997). This is the area for success. If the feeling of success about the learning happens, the condition for learning is set.

The new learning goes through a process from working memory to long-term storage. With the first two conditions met, the brain can become involved in the learning.
There are two criteria against which the brain accepts or rejects the learning. The first relates to the brain making sense of the experience or can the learner understand based upon past experiences (Llewellyn, 2001). The brain begins to retrieve past experiences, or prior knowledge, and the process of making sense begins. The learner, either internally or externally, connects the new with the old. If it makes sense, the brain moves to the next its next criteria. If it doesn’t, the learner is grappling to make sense. If the physical materials are frustrating or are not quality and/or the concept is beyond the scope of experience, the brain will reject the new learning.

The second criteria speak to making meaning. This is individual. Following the recommendations of the NSRC, the use of research-based curriculum has attempted to circumvent this be eliminating topics that are not appropriate or lack the interest for sustainability (NSRC, 1997). In summation, the greater the presence of meaning to the life of the learner and the higher the presence of sense to the learner, the greater the probability of storing information (Dewey, 1934; Jensen, 1998; Llewellyn, 2001; Piaget, 1964).

“The total of all that is in our long-term storage areas forms the basis for our view of the world around us” (Llewellyn, 2001, p. 51). This relates directly to the long range goal for science reform. One goal was to make for a citizenry that is informed about the issues. If there is not adequate storage of information and a meaningful retrieval system, a citizen would make decisions based upon inadequately formed facts, concepts, and/or understandings. The recommendation for using inquiry as one of a preferred method for learning is strengthened. In conclusion, to develop the broad base needed to make
decisions in the global community, the more items accumulated, “the number of possible combinations [for problem solving] grows exponentially” (Llewellyn, 2001, p. 51).

**Professional Development**

Teachers must develop a belief about the viability of using the philosophy of inquiry before the practice can be incorporated into classroom practice (Fullan, 2001; Hall & Hord, 2001). The NRC (1996), in their standards, states that the activities in professional development should be offered to

- create opportunities for teachers to confront new and different ways of thinking;
- to participate in demonstrations of new and different ways of acting; to discuss, examine, critique, explore, argue, and struggle with new ideas; to try out new approaches in different situations and get feedback on the use of new ideas, skills, tools, and behaviors; to reflect on the experiments and experiences of teaching science, and then to revise and try it again (pp. 67-68).

In other words, the experience of the teachers should be analogous to the learning to be done by their students (Bybee & Loucks-Horsley, 2001; Guskey, 2000; NRC, 1996; Vasquez & Cowan, 2001). In other words, “change as growth or learning . . . teachers are themselves [the] learner” (Clarke & Hollingsworth, 2001, p. 948).

This philosophy of teachers replicating the experience of their students is core to the intervention, the ASSET Institute for Inquiry. The facilitators model exemplary pedagogy and demonstrate pedagogical content knowledge (PCK) throughout the Institute. The facilitators have as part of their repertoire of behavior built in pauses for
identification of roles and discussion points about what is the student role and what is
the teacher role. These facilitation skills are modeled after the Exploratorium.

The intent of professional development is to help professionals construct strong
connections between theory and practice. It should take a professional from where they
are to where they want to be. A model that is supportive of this philosophy of teacher
change was developed by Susan Loucks-Horsley and colleagues. It is embedded in the
Strategic Planning Institute delivered through the National Science Resources Council in
their Leadership and Assistance for Science Education Reform (LASER) project. A
derscription of the content of the model and the intended outcomes is essential in
understanding how the change in teaching practice from traditional to inquiry can be
accomplished.

The core to successful professional development rests with the knowledge and
beliefs part of the model. It is in what is known about teaching for learning that is
significant for change. What is known and believed about children as learners is the
baseline of the science reform efforts. It is here that a commitment to how learning can
happen with children must take place, even if it is cursory at the outset.

It is at this juncture that the context of teaching realities must be examined.
Knowing where you are starting is important for knowing where you are going and how
you will know you got there (Holcomb, 2001). Teachers must be aware of where they
are beginning in regard to the practice of inquiry within their classrooms. Next, goals are
established around the critical factors relevant to the indigenous classroom. The Loucks-
Horsley model offers a myriad of strategies for assisting in implementing the model.
Execution of a professional development plan happens through a commitment to a belief
about how teachers and students learn, to a context in which to present the new process, an awareness of critical issues that might undermine the professional development experience, and to a list of strategies for presenting this new process, the teaching of science through inquiry. As with all good plans, assessment of the professional development experience is critical. It is important for the assessment to center around the learning opportunity and around the vehicle that delivered the learning experience.

What happens in the professional development experience that replicates the learning we want our students to do? That is the underlying question essential to the development, design, and delivery of the intervention. The approach is substantiated when reviewed against the six research-based factors that offer “great potential for achieving results” (Birman, Desimone, Porter, & Garet, 2000, p. 28). The six factors are the structure of the sessions, in-depth sessions, supported participation, content and process of topic (i.e., inquiry), active participation, and a community of learning (Birman, Desimone, Porter, & Garet, 2000).

The structures of the IFI sessions are a combination of the aforementioned elements. Teachers are mentored, conduct a research into inquiry into their classrooms, and work in a community of learners. The IFI is in-depth through five full days that encompass the theory, practice, and implementation of inquiry into the respective classroom. The scaffolding of the sessions and the facilitation skills of the faculty contribute to a community of learners. The majority of the sessions are activity-centered and learner-centered. With the culmination of the IFI, there is a fostering to encourage translation of the theory into practice.
Incorporated into the structure of the IFI is a philosophy of andragogy. Andragogy replicates the learning process as explained mirrored as pedagogy (Knowles, Holton, & Swanson, 1998) but with adult learners. The major difference between pedagogy and andragogy resides within the learning. With pedagogy, the responsibility for scaffolding the learning rests with the teacher. With andragogy, the responsibility of the learning is with the adult learner working in tandem with the teacher. The principles of adult learning that are incorporated are the following characteristics:

- Adults are autonomous and self-directed. Adults need to be free to direct themselves. Their teachers must act as facilitators, guiding participants to their own knowledge rather than dispensing facts.

- Adults have a foundation of life experiences and knowledge that is work-related. Adult learners need to connect their learning to this knowledge/experience base. Theories and concepts must relate to the learners.

- Adults are goal-oriented; therefore, an educational program that is organized and clearly defined is essential. This must be done at the onset of the professional development experience.

- Adults must see a reason for learning something. It must be applicable to the work. This means that theories and concepts must relate to the participants and their experiences.

- Adults are practical, so teachers must tell the adult learner how the lessons will be useful to their teaching.
- Adults must be shown respect. The adult learner must be treated as equals in experience and knowledge and allowing voicing of their opinions freely in the class (Lieb, 1991).

These principles are essential for the outcome of the Institute of Inquiry which is the use of the information taught in the course in their classroom. This transference is most likely to occur when:

- Participants can associate the new information with what they already know;
- Information is similar to a logical framework of their teaching experience;
- Original learning was high; and
- Information contains elements extremely beneficial to their teaching (Lieb, 1991).

Intervention

**Background**

As is the practice of the American education system, the medium for reform, or renewal, resides in the educational system, specifically with the process of teaching and learning in the classroom. Lessons learned from the past, supported through data collected in the 1980s, the collective wisdom from AAAS, NSTA, NRC, NSRC, combined with the money and resources from Federal agencies, came together as research-based curriculum in the 1990s.

From the data gathered about the experiential curricula, ESS, S-APA, and SCIS, there were elements recognized as needed to ensure the use of inquiry-based science in classrooms. In addition, these curricula were reflective of child-centered theory.

Furthermore, as a result of the data collected by NSTA (Lopez & Schulz, 2001; Penick, 1983) and the work of Doug Lapp, the NSRC identified and supported five elements essential for the implementation of curriculum. These elements become the model for change. This model is the process for attainment of the goals for science education designed to ensure their impact for all citizens of America. A definitive description of the National Science Resources Center’s five elements is presented as the framework.

One, the curriculum materials should be units or modules, focusing on a different area of science and technology. Two, professional development, a process by which school systems prepare teachers to use the curriculum and to advance their pedagogical experiences, must be on-going and in-depth. Three, a materials support center is needed to ensure that teachers have access to the science materials they need to facilitate science instruction. Four, an assessment system that intends to assess what students truly know and can do as a result of their experiences with the science materials must be in place. Five, support within the school system and the community-at-large is essential because the combined support encourages initialization and subsequent institutionalization of the success of a science program.

This comprehensive approach is called systemic reform (NSRC, 1997; Smith & O’Day, 1990). These elements
just described make up the ‘system’ needed for building an effective elementary science program. More than thirty years of experience have shown that addressing only one or two of these elements – the science curriculum or professional development, for example – is not enough. All of the elements are equally important and must be addressed simultaneously over a sustained period of time – at least five years – to ensure the institutionalization and long-term success of the program (NSRC, 1997, p.3).

In 1995, the National Science Foundation (NSF) funded Local Systemic Change Initiatives (LSC). “The goal of the LSC program [was] to improve the teaching of science, mathematics, and technology by focusing on the professional development of teachers within whole schools or school districts” (Weiss, Banilower, Overstreet, & Soar, 2002, p. 1).

This funding afforded Local Systemic Change Initiatives opportunities to impact educational communities. The grant required the LSC to implement their indigenous project using the aforementioned structure of the NSRC, with a strong “emphasis on preparing teachers to implement designated exemplary mathematics and science instructional materials in their classrooms” (Weiss, Banilower, Overstreet, & Soar, 2002, p. 1).

In 1992, through the efforts of the Bayer Corporation, an application to establish a LSC in southwestern Pennsylvania was submitted and approved. This gave birth to the Allegheny Schools Science Education and Technology Incorporated (ASSET Inc.) project. The requirements of the grant addressed the five essential elements identified by the NSRC thus ensuring a rigor that would offer the best opportunity for rooted
sustainability. ASSET Inc. followed the recommendation of the National Science Resources Center (1997) and implemented all five simultaneously.

**ASSET Inc.**

Initially, the parameters of the LSC structured the scope of the work of ASSET Inc. to include sixteen school districts in southwestern Pennsylvania. Within the first year, to meet the demand, ASSET Inc., under the directorship of Dr. Reeny Davison, applied for and received extra funding to include an additional fifteen school districts. These thirty-one districts became the core.

Within the initial year, ASSET established a materials support center to distribute the NSRC recommended curricula of STC, FOSS, and Insights. In addition to delivering the curriculum, the materials support center would refurbish each module. The materials met the requirements of quality and reliability that is essential to experienced based science (NRC, 1996, 2000).

Coupled with the endorsed curriculum, known as modules or kits, was the requirement that the teacher using it follow the model of professional development of training by a teacher who had experience with the module (NSRC, 1997). The notion of teacher training teacher was a core belief of ASSET Inc. Also, it met with the standards set forth in the NSRC’s five elements. This training by teachers expanded the concept of professional development as a result in part to the NSF requirement of one hundred hours of professional development through the five years of the grant (Weiss, Banilower, Overstreet, & Soar, 2002).

The element for building community support was first addressed with initial commitment letters from superintendents from the thirty-one districts. The
superintendents agreed to develop an infrastructure that would support the change process. Science nights, school board meetings, and summer institutes were vehicles used for the continuous movement from implementation of inquiry-based science in elementary classrooms.

Assessment followed the model. There was assessment related to instruction and there was program assessment. Each addressed support of the reform. The instructional assessment was based within classroom practices. The elementary classroom teachers of science were involved in the development of the assessment tools related specifically to the modules. This teacher-led student-based research fostered the philosophy of active participation by the users of the assessment tools, the teachers (Costa & Garmston, 1994; NRC, 2001).

**Evolution of Institute for Inquiry**

Underlining the change from traditional methods for teaching science to child-centered inquiry-based science is professional development. As the program was implemented it was expected that teachers would follow predictive paths as they evolved through the change process initiated by the LSC, ASSET Inc. A program for professional development was designed. It was researched based and followed the prescriptive program offered by the NSRC (1997).

The professional development program of the National Science Resources Center was a three phase model of change. Their experience showed “that most teachers go through at least three phases: novice, competent, and expert” (NSRC, 1997, p. 82). Their recommended program is shared because the teachers involved in the ASSET project
evolved in a similar manner that is important in the evolution of this researcher’s intervention, the Institute for Inquiry.

The novice, or introductory phase, begins with intensive introduction with child-centered, hands-on, inquiry-based science. The basics of the use and implementation of the curriculum is discussed. The discussion is led by teachers who have had similar experiences, shared common concerns, and could offer strategies for managing their classroom environment through the change process. This stage is mechanical for the classroom teacher new to child-centered science.

As teachers begin to feel comfortable with curriculum and its related issues, they begin to modify lessons to reflect the needs of their students (NSRC, 1997). This is the competent stage. Here the professional development program moves to a new demand.

Teachers are now interested in exploring in greater depth such topics as constructivist theory and the learning cycle, cooperative learning techniques, assessment strategies, and how to manage science into other areas of the curriculum. Many teachers are also interested in learning about the science content of the modules they are teaching (NSRC, 1997, p. 84). This new demand emphasizes the need for on-going, in-depth professional development (Loucks-Horsley, et. al., 2003; Loucks-Horsley, et. al., 1998). To meet this demand and to support the change process the initial letter of intent signed by superintendents partially addressed this.

The final stage is the expert. Teachers who have attained this level distinguish themselves as “skilled observers of students, as well as being knowledgeable about science and how it is learned” (NRC, 1996, p. 33). These teachers move through their
classrooms engaging students in ideas, listening to conversations, and answer and ask questions to help move students to the next level of their respective understanding. These expert teachers know when to “match their actions to the particular needs of the students, deciding when and how to guide – when to demand more rigorous grappling by students, [and] when to provide information” (NRC, 1996, p. 33).

The convergence of the second and third stage generated a need for more in-depth professional development. A group of individuals called ASSET Resource Teachers (RT) took the initiative and morphed the Exploratorium’s Inquiry Institute to meet the needs of the thirty-one school districts ASSET serviced. To explain this morphing, a description of the Resource Teacher and their own professional development is needed.

**ASSET Resource Teachers**

One of the core beliefs of the ASSET Inc., as an LSC, was teachers leading teachers. The National Science Resources Center (1997) suggests incorporating the concept of lead teachers into the LSC. ASSET took the concept of lead teachers to a level of mentor, or resource teacher. Teachers were asked to step out of their classrooms for two years and become the link between theory and practice.

Part of the philosophy in action by ASSET was to offer opportunities for the RTs to follow a personal plan of professional development. The RTs were encouraged to explore their stages of development. As they moved from novice to competent their need for exploring in greater depth the pedagogy of inquiry advanced. In matching their growth to need, some RTs traveled to the Exploratorium and participated in the Inquiry Institute designed for providers of professional development. The elements of the Exploratorium’s institute became the model for ASSET’s Institute for Inquiry, with one
major change that will be noted after a discussion of the elements of each program and their related objective.

Both institutes share the same experiences. First, the participants are put through an experience intended to raise their awareness of three methodologies for instruction – teacher directed, guided exploration, and open-ended exploration. This activity ends with a facilitated discussion about the viability of each method. The next chunk of time within the institute is to foster an awareness of how information is processed by learners. Those process skills that are indigenous to learning through experience are emphasized.

An essential element in inquiry-based instruction is the tool of questioning. The teachers at the institute participate in an activity that develops the role of questions from the perspective of the learner and the teacher. In addition, questions that are the basis for inquiry are explored. With these three elements exposed for exploration, the participants are asked to apply these concepts to their own inquiry.

Inherent in the design of the next activity, is an opportunity to develop a curiosity that is innate to the participant relating to topics such as light or balance. This curiosity is transcribed into a question for exploration. From here the participants are engaged for about nine hours, with support, to explore their own interest in the form of an investigation. At the end of the activity, the model of what scientists do is fostered when the participants are required to report their findings.

The next step is to begin the translation of theory to their personal practice. The participants are asked to redesign a lesson incorporating their new base of information. There follows skillful facilitation to identify the elements of the process as it relates to
learners, themselves and their respective students. After this is where the two institutes change course.

The Exploratorium asks the participants, as providers of professional development, to design a strategic plan to translate this information into their professional development in their respective locations. The ASSET institute, designed and delivered to practitioners, asks the participants to develop a plan for implementing the inquiry theory and philosophy into their respective classrooms. In addition, the participants of the ASSET institute have the added support of the RT.

The design of the role of the RT is to nurture, foster, and support the teacher in the implementation and practice of inquiry in their classrooms. One way this is addressed is through site visits. The RT will visit the Institute for Inquiry participant on their home turf and assist them in the translation of inquiry to practice. This assistance can be as coach through the initial stages of practice, as a model of the practice, and/or as a mentor through the process of change. Ultimately the participant must practice using inquiry.

After a course of five to eight weeks, the participants return to the site of their institute and share their findings. These findings should demonstrate inquiry in action and reflect the path of growth the participant traveled as they moved along a continuum of beginner in the practice of using inquiry.

At this juncture in the process, the teachers are engaged in a discussion about brain research. It is an attempt to support the use of inquiry based learning and to help facilitate their work with their students. This piece ties to the previous discussion about meaning and sense for the learner’s brain to store the information. If the sum of their
institute experience can be stored in their long-term memory, it will become part of their belief system (Llewellyn, 2001; Piaget, 1964). Teaching is belief in action (Hurd, 1993).

Educational Change

The purpose of the LSC was to impact change in regard to the teaching of science in elementary classrooms. As an LSC, ASSET implemented their strategic plan against a backdrop of the NSRC’s five elements essential for successful implementation of a course of reform in science education. Their strategic plan has a strong emphasis on professional development (NRC, 1996; NSRC, 1997). True to prediction, the teachers moved along the continuum from novice to expert in their understanding and implementation of inquiry-based science (Danielson, 2000; NSRC, 1997). From this movement evolved the Institute for Inquiry.

The Institute for Inquiry is designed and delivered to cause a change in belief about the process of teaching science. The participants are members of school districts that have adopted curriculum that is inquiry. They have used the strategies in the manuals to implement their science curriculum. The Institute for Inquiry is structured to change their belief about the teaching for learning process.

Change is a process that takes between five to seven years (Fullan, 2001; NSRC, 1997). The Institute for Inquiry models the Piagetian theory for learning. The translation of the new learning to practice requires support. The questionnaire is designed to unveil what has been addressed and if it is happening.

The questionnaire has three embedded sets of item that mirror Fullan’s three elements for change or implementation to occur. One set of items, incorporated from the
original Horizon piece, reflect the use of curriculum and related materials. Another set of items, through analysis, will focus on the process of shifting a belief in action, their teaching, from a traditional practice of teaching science to one of teaching science through inquiry. There are items that explore the practice of teaching science through inquiry. With this self-reported approach that asks participants to reflect before and after the intervention, an analysis of the data a portrait of teachers in the process of change will be painted.

**Summary**

The history of educational reform has been in reaction to a need politics, society, and the education profession itself. Society has stressed the enculturation of immigrants. Political agendas have been from special interests groups or deemed part of national issues. Also, there has been influence from within the profession theorizing traditional or experiential approaches to teaching. These three groups, societal, political, and educational, have not been mutually exclusive. There were times, such as the 1960s and the 1980s, when two of these groups joined forces to implement change. What is unique about the educational reform of the 21st century is the convergence of all three groups, coupled with the influences from the fields of psychology and medicine, to influence the reform of the educational system specifically in science.

These groups, independently and then somewhat collectively, through their respective research support the intent of each to the other. In the 1990s, there was a melding of wisdom with the direction of the needs of the citizens of America. For the first time, all entities, enjoined by business, supported a plan for reforming the educational system, specifically science. This plan is research based and includes lessons
learned from past reform efforts (Bybee, 1993; Lopez & Schulz, 2001; Penick, 1983; Presseisen, 1985).

An outcome of the reforms attempted with LSC grants was an institutionalization of the process into the educational system. With this said, it is important to determine if the reform has changed the system or has the system changed the reform (Fullan, 2001; Hall & Hord, 2001; Hord, Rutherford, Huling-Austin, & Hall, 1987; Joyce & Showers, 1995; Presseisen, 1985). With inquiry identified as the philosophy and theory behind the science reform, it is imperative to discern the translation to practice. Herein lies the intent of this research question, are classroom practitioners incorporating inquiry into their teaching for learning process?

One approach is in the questioning of teachers about their practices against three areas of change, as identified by Robert Fullan (2001). The three areas Fullan identified for the implementation of change are: (1) use of new materials, (2) use of new pedagogical practices, and (3) use of a new belief in classroom practice. As teachers become experts in the field of science teaching, does an in-depth professional experience, such as an inquiry institute, foster change? An analysis of teaching practice against a backdrop of Fullan’s theory about change, will offer data that will indicate practice of inquiry in K-5 classrooms. If inquiry is reported as being practiced, the next levels of questions revolve around what inquiry in the classroom looks and feels like. If it is not being practiced, what elements are involved would be the next research question.
CHAPTER 3

“The Butterfly Effect: A butterfly stirring the air today in Peking can transform storm systems
next month in New York.”

Gleick, 1988, p. 8

METHODOLOGY

Overview

The history of reform for the American educational system has had conflict over the preferred method for teaching children in K-5 classrooms, centering on teacher-centered versus child-centered methodology. One root of the controversy is which of these two methodologies would meet the goal of educating each American to be a fully contributing member of society who can make informed decisions. The last two decades have produced a recommendation for achieving this goal, use of the pedagogy of inquiry. Inquiry involves a teaching for learning cycle that mimics the practices of scientists to develop habits of mind that correlate to the goal of each citizen of America being a contributing member of society through informed decisions.

The pedagogy of inquiry is indigenous to the natural way human beings interact with their world. Whenever such an interaction occurs, the mind processes the new information against what has already been learned, or stored in the mind. This interaction either can affirm a held belief or challenge that belief. It is within this challenge that the opportunity for learning rests, either as an informal self-regulating experience or as a formal experience, e.g., a classroom.

Opportunities for learning through inquiry can be replicated in classrooms using quality materials for hands-on experiences that generate a challenge to an existing belief or support a previous learning. This method parallels the constructivist philosophy for
learning and is supported further by current cognitive research on how the brain processes information for later retrieval, or learning.

With inquiry defined and with cognitive research to support a teaching for learning method to best attain the goals and the drivers of reform set forth in Chapter Two, it again falls to the educational community to test the validity and reliability of this theory of teaching science through inquiry. The testing of this theory begins with the practitioners.

To begin the process that contributes to the validation of inquiry as the better method for instruction, a model must be constructed. The model must deliver the philosophy of inquiry and the elements inherent to the practice of inquiry. The framework for delivery is professional development that models the inquiry experience as it immerses the participants in the process. Herein lays this body of research.

Questions

The foundation of this research is the struggle of change in the teaching of science in K-5 classrooms. The struggle is fundamental when change is defined as the cognitive moment when a new approach to teaching science to elementary children causes reflection and it is within this reflection that a different thinking regarding a belief about philosophy expressed through pedagogy emerges (Dewey, 1938; Fullan, 2001; Sousa, 2001). The thinking that occurs at this cognitive moment is learning. In the teaching for learning cycle, whether as pedagogy or andragogy, an opportunity must exist for this cognitive moment to occur.

The use of models is an effective technique in enhancing those opportunities constructed by teachers in the teaching for learning cycle (Sousa, 2001). The adaptation
of concepts into effective models for instruction is basic to the practice of inquiry. The intervention central to this research study is a model of inquiry in practice. The framework for this professional development is an approach that is centered in a series of experiences that models inquiry as it develops the inherent philosophy and pedagogy of inquiry. With this, as with the teaching for learning cycle, what is needed is translation of inquiry into practice.

This translation into practice is the central impetus behind this study, in uncovering the role inquiry as professional development can have in reforming the current methodologies used in K-5 classrooms to the teaching of science through inquiry. For this reform to occur a lens is needed through which to observe the change. Fullan (2001) has identified three dimensions that are critical when implementing a new procedure in the educational system. The three, curriculum, teaching strategies, and beliefs, will be the three lenses for observing change. The questions guiding this research are:

**Question 1**: To what extent does the IFI impact the use of curriculum in the teaching of science through inquiry?

**Hypothesis 1**: A statistically significant relationship will exist between the frequency of use of the curriculum and the completion of the IFI.

**Question 2**: To what extent does the IFI impact a change in pedagogy relating to the teaching of science through inquiry in K-5 classrooms?

**Hypothesis 2**: The data will indicate a statistically significant relationship between the completion of the intervention and the change in practice when teaching science through inquiry.
Question 3: To what extent does the IFI impact a change in beliefs about teaching of science through inquiry as practiced in K-5 classrooms?

Hypothesis 3: The data will reveal a statistically significant relationship between the frequency of use of inquiry as philosophy in practice and the IFI.

Question 4: Is there a relationship between the years of teaching experience and the frequency of use of inquiry in K-5 classrooms?

Hypothesis 4: The data will indicate a statistically significant relationship between years teaching and the use of inquiry.

Question 5: Is there a relationship between the completion of the IFI and the use of inquiry in K-5 classrooms?

Hypothesis 5: There is a statistically significant relationship between the time of completion of the IFI and the frequency of use of inquiry in teaching.

Question 6: Is there a relationship between the practice of teaching science through inquiry and the frequency of use of a resource teacher?

Hypothesis 6: There exists a statistically significant relationship between frequency of use of inquiry and the frequency of use of the resource teacher.

Questionnaire Construction

The instrument to collect data is a survey originally developed by Horizon Research, Inc. for the National Science Foundation (NSF). It was designed as a lens through which to filter the degree of teacher enhancement in the teaching of science in elementary classrooms with Local Systemic Change projects funded by the NSF. With a contact to Ira Weiss, Director of Horizon Research, Inc., permission (Appendix A) was granted to use their survey for the purposes of this dissertation.
For this questionnaire to be the filter to determine the impact the IFI has in changing the pedagogical practices of K-5 teachers, the questionnaire was restructured (See Appendix C). Those items not pertaining to the lens of change reflective of this research were deleted. The decision for which items to keep and which to delete centered on their relationship to Fullan’s (2001) three dimensions in implementing any new procedure:

1. Change in curriculum, i.e., use of new instructional materials and related practice;
2. Change in the use of new teaching strategies, i.e., pedagogy of inquiry; and
3. Change in beliefs about pedagogy and learning theory, i.e., use inquiry as the primary method for teaching science.

The three dimensions “are necessary because together they represent the means of achieving a particular educational goal” (p.39), which for this research involves a change in the teaching for learning cycle. They are but one lens for viewing change.

With the questionnaire restructured, the first lens, concerning change in the practice of teaching science through inquiry, asks the respondents to reflect upon their teaching style prior to the intervention of the IFI. This question asks the participants to reflect on their teaching of the science curriculum. For this research question, curriculum is defined, according to the NSRC, as an incorporation of the appropriate pedagogical practices, science content, and the overall presentation and format of the material (1997). The same question is repeated asking the respondents to reflect upon their current teaching practices since the intervention. Each set of questions, before and after the intervention, asks the participants to respond in relation to the frequency of use.
The second lens for which the questionnaire acts as a filter is in regard to change in teaching practice. Embedded in the questionnaire are questions asking for the participant to rank their frequency of use of inquiry and their frequency of use of the more conventional practices for which the intervention was to change or cause to diminish. The items are a compilation of the National Science Education Standard for teaching (NSRC, 1996, p. 52).

The NSES has established recommended changes in emphases from conventional methods to the pedagogy of inquiry (NSRC, 1996). The indicators provide a focus which highlights change in the teaching for learning cycle by accentuating those practices that are not supportive of teaching science like scientists and emphasizing those practices that support teaching science through inquiry. Again, the items are presented twice, asking the participant to reflect upon their teaching methods prior to the intervention and then in indicating their current practices.

The third lens is for beliefs about what is important to teach. The questionnaire addresses, through a series of questions relating to the practice of inquiry, what the teaching of science in K-5 classrooms should resemble. The NSES (NSRC, 2000) has established these indicators of practice. The respondent indicates the degree of use and the frequency of use since the intervention.

The items are written using a Likert scale asking the individual to rate the frequency of practice relating to their teaching science as their pedagogical philosophy in action. The items are arranged in a random order intended to not lead the respondent’s answers (Dillman, 2000). The remaining items in the questionnaire are being used as qualifiers, (e.g., years of teaching, number of minutes per class science is taught, etc.).
Prior to the questionnaire being mailed to the population, the questionnaire was tested by a class of undergraduate education majors and ASSET teachers. This was done to eliminate any confusion and to ensure the efficacy of the questionnaire (Thomas, 1999). Guiding questions to determine ease at which the questionnaire can be completed was asked against a checklist (Dillman, 2000; Thomas, 1999) to assist with the ordering of the items, their format, and effectiveness of the sequence. In addition, a mean time for the completion of the questionnaire was gathered for inclusion in the cover letter as information to those to whom the questionnaire is being sent.

**Population**

The population to receive the questionnaire will be all of the 208 K-5 elementary science teachers who participated in a five-day Institute for Inquiry (IFI) between the fall of 2000 and the spring of 2003. The IFI is the flagship professional development opportunity offered by ASSET Inc. subsequently, the population is encouraged to attend or request permission to attend. The population is comprised of attendees from the districts serviced by ASSET Inc. in the Southwestern region of Pennsylvania, primarily Allegheny County.

There will be a letter mailed to the graduates of the IFI to alert them of the arrival of the questionnaire and its purpose. The questionnaire will be mailed to the graduates with a follow up mailing within one week of the initial mailing. The questionnaire will include a code intended to track the return of the questionnaires. For this purpose, a list of participants to whom the questionnaire was sent will be maintained for the strict
purpose in tracking returned questionnaires. It will be kept in strict confidence and
destroyed once the cutoff date has been met.

Everything will be done to achieve an expected rate of return of 80%. The
questionnaires will be completed anonymously. The only information that could be a
possible identifier would be their date of graduation from the IFI. There will be a cover
letter included clearly indicating how confidentiality will be addressed, an overview of
the project, the reason for the request of the participant’s time, the amount of time needed
to complete the questionnaire, and identification information about the researcher.

**Analysis**

As descriptive or correlational research, this design centers on the collection of
data through a questionnaire to determine whether, and to what extent, relationships
exists between the intervention and one or more variables. The extent that there exists a
statistically significant relationship, positive or negative, between two or more variables
will be used to articulate a portrait of teachers in the change process. Later, in chapter
Five, the identification of any statistically significant elements will be used in
strengthening the resolve, further development, and the facilitation of a future Institute
for Inquiry. The direction will be in how to better scaffold the transition to practice in
using inquiry as the method for teaching science through inquiry.

The treatment (independent variable) is the participation in the IFI. The extent
there is change toward teaching science through inquiry (dependent variable), expressed
as use of science curriculum, shift in philosophy about teaching and learning science, and
the practice of teaching science through inquiry, is self-reported.
After the restructuring, those items remaining are identified and used in describing the teaching practices of the participants before and after the intervention. The existence of a relationship between the intervention and change in practice for teaching science through inquiry will be described through the three essential elements necessary for change to occur (Fullan, 2001), materials being the first. As defined for this study, the three aspects necessary for change involve using: (1) new materials to accompany the new practice; (2) new teaching practices that compliment the new materials; and (3) altering beliefs, as necessary, to accompany the new materials and teaching practices (Fullan, 2001).

The questionnaire items used to generate the data relating to the three essential elements of change will be disaggregated according to three sets: materials, teaching practices, and beliefs about how students learn. Each of the three data sets is further divided into two subsets representing the reflection before and after the intervention. In deciding which items will be disaggregated into which set, a conceptual definition for materials, teaching, and beliefs is needed.

First, the National Science Resources Center describes curriculum materials as kits, manipulative materials, models, field work, independent investigations, performance tasks, notebooks, appropriate pedagogical practices, and the overall developmentally appropriateness of the presentation (1997). This description was used to identify questionnaire items six and twenty as the data collection points relating to materials. The questionnaire item contains a delineated list of statements relating to curriculum materials and the respondent is asked to indicate their use from one to five. The treatment of the data will involve calculating a mean score for each of the five possible indicators of use
for each listed statement. The mean score will represent average use for each of the identified items relating to curriculum materials. A data table labeled Curriculum Materials will be constructed containing the mean frequency of use for each subset statement placed in the appropriate before or after column.

Second, the National Science Education Standards articulates change in teaching as moving from teacher-centered classrooms to student-centered classrooms. The movement involves adopting behaviors that replicate scientists. To further define, the elements include student driven questions, selection of materials, gathering evidence, explaining the evidence related to the question, and communicating a justifiable explanation (NRC, 2000). The questionnaire items that will be the data collection points for teaching are identified by the researcher as questionnaire items one and eighteen. The questionnaire item asks for reflection pertinent to before and after the intervention. In addressing the specific practices of teaching science through inquiry, the questionnaire item is articulated further into statements to which the respondent is asked to indicate degree of use on a one to five scale. The statements will have a mean calculated for each degree of use. A data table labeled Teaching Practices will be constructed containing the mean indicator of use for each subset statement placed in the appropriate before or after column.

Third, teaching is a philosophy in action, or doing what you think (Fullan, 2001) is the right thing to do. A philosophy is a belief system (Webb, Metha, & Jordan, 2000). When teaching occurs it is philosophy in action because “teachers teach what they believe in” (Hurd, 1993, p. xiii). The item identified by the researcher to indicate change in belief about the use of inquiry as the method most often used in teaching science are
questionnaire items two and seventeen. Each item has a delineated subset asking the respondent to reflect on the importance of use before and after the intervention. A mean will be calculated for each of the five indicators of importance of use for each of the subset statements. A data table labeled Beliefs will be constructed containing the mean indicator of use for each subset statement placed in the appropriate before or after column.

With the three necessary items analyzed, an over arching picture of change is needed. The questionnaire items selected all ask the respondents reflect on the use of the materials, the teaching, or a belief in practice. In addition, the questionnaire items all have five levels of response. With this as the common element and the items in the questionnaire reference the three essential elements for change, the data will be analyze in relationship to the individual hypotheses.

Hypothesis 1: A statistically significant relationship will exist between the frequency of use of materials and the completion of the IFI.

Analysis Hypothesis 1: Using SPSS, the data aggregated from the questionnaire relating to the use of curriculum materials will be descriptive. The data is entered as nominal data. The descriptive analysis will be looking at frequencies of the mean and the standard deviation. This statistical data will be used in describing the frequency of use of materials and the completion of the IFI. In addition, a Related Samples t Test will be done comparing responses for before and after the intervention for each of the subset of items under the curriculum materials questions. The Related Samples t Test will indicate a statistical significance between the before and after.
Hypothesis 2: The data will indicate a statistically significant relationship between the completion of the intervention and the change in practice when teaching science through inquiry.

Analysis Hypothesis 2: The NSES has standards relating to the teaching of science using inquiry. The teaching standards are summarized according to behaviors that demonstrate a shift from conventional teaching of science toward teaching practices that are inquiry-based. The summarization is a two column chart with eight descriptive behaviors, or teaching practices, in each column. One column identifies behaviors that should be used less frequently in teaching science. The other column identifies behaviors as being more appropriate in using inquiry as the primary methodology in the teaching science.

In the construction of the questionnaire, the sixteen indicators were mixed randomly for the sole purpose to not leading the respondent (Dillman, 2000). The sixteen descriptors of behavior appear twice with the first occurrence asking for the response to be reflective before the intervention and the second occurrence to indicate after the intervention. Both appearances of the sixteen descriptors of behavior require the respondent to indicate from one to five, the frequency of use when teaching science in their K-5 classroom during their typical teaching week. An indication of a one means this practice is never used; with a five to indicate frequent or constant use of this method when teaching science.

Using SPSS, the data will be descriptive analysis for the entire population. The analysis will be for frequencies of the mean and the standard deviation. This information will be used to describe teaching science by the participants. The data is entered as
nominal data. This statistical data will be used in describing the frequency of use the
two teaching methods. In addition, a Related Samples t Test will be done comparing
responses for before and after the intervention for each of the two subsets within the
question in regard to teaching methods. The Related Samples t Test will indicate a
statistical significance of use of methods between the before and after.

Hypothesis 3: The data will reveal a statistically significant relationship between
the frequency of use of inquiry as philosophy in practice and the IFI.

Analysis Hypothesis 3: Using SPSS, descriptive statistics will be computed to
describe the behavior in the teaching of science against the NSES on Inquiry. There are
five essential indicators of inquiry in practice which will be used in describing the
behavior of the teachers of science who have attended the IFI. This will contribute to the
portrait of teachers and the impact of professional development.

Hypothesis 4: The data will indicate a statistically significant relationship between
years teaching and the use of inquiry.

Analysis Hypothesis 4: Using SPSS, correlation will be used to measure and
describe the relationship between the number of years of teaching experience and the
frequency of use to each of the five indicators of practice, or beliefs. A positive
correlation will indicate a relationship between years of teaching experience and a higher
frequency of use of the five indicators. A negative correlation will indicate a relationship
between fewer years of teaching experience and the higher frequency of use of the five
indicators or the higher years of teaching experience and the lower the frequency of use
of the five indicators. This statistical information will be useful in the verbal portrait
about teachers and the change in their in practice of teaching science using inquiry as it
relates to years of experience. This information would be useful in the further design and development of the IFI.

Hypothesis 5: There exists a statistically significant relationship between frequency of use of inquiry and the frequency of use of the resource teacher.

Analysis Hypothesis 5: Using SPSS, the Pearson $r$ will be used to determine a statistically significant linear relationship between frequency of use of the five indicators of inquiry in practice and the role of the resource teacher. A positive correlation would indicate a high frequency of use of the indicators of inquiry in practice with a high frequency of use of the RT. This statistical information becomes critical for this researcher because the RT is a teacher helping to scaffold the learner, the classroom teacher, into application of the new pedagogical practice of teaching science through inquiry.

Hypothesis 6: There is a statistically significant relationship between the time of completion of the IFI and the frequency of use of inquiry in teaching.

Analysis Hypothesis 6: Using SPSS, the Pearson $r$ will be used to determine if a statistically significant relationship exists between length of time since completing the IFI and the frequency of use of the indicators of inquiry in practice. A positive correlation will mean that individuals who have a higher frequency of use of inquiry in their practice will have the longer the time interval since completing the IFI. This will be a significant piece of the portrait of teachers of science because the new pedagogy indicates a change. A higher use of the indicators of inquiry in practice means inquiry is the preferred method for teaching science through inquiry which is the goal of this research.
Summary

The lenses for determining change are the three elements deemed significant by Fullan. The lenses are curriculum, teaching strategies, and beliefs about what is important (Fullan, 2001). The filter through which the lenses can focus is the questionnaire. It was structured around the three elements. The goal is to have the belief system, or philosophy about what is important in teaching, change relating to the teaching of science through inquiry. The teaching for learning cycle is at the heart of the educational system. The first step in changing the cycle is teaching. If the process of teaching can change, the next step is to study the effect on learning. The next question would be: Does teaching science through inquiry impact the learning of students in K-5 classrooms?
CHAPTER 4

“In meaningful learning the very process of acquiring information results in a modification of both the newly acquired information and of the specifically relevant aspect of cognitive structure to which the new information is linked.”

Ausubel, 2000, p. 3

RESULTS

Overview

The results presented are from the data collected through the questionnaire to determine impact of an intervention, the ASSET Institute for Inquiry, upon practices of teachers in elementary classrooms. The chapter is organized around the six research questions. Each research question is presented with a description of the data used and the statistical process used for analysis. In addition, the statistical significance, as it relates to each research question, is established. The analysis incorporates descriptive, inferential, and correlational or associational statistics. Each of these will answer the research questions. A context to assist with the analysis begins with demographic information revealed through the questionnaires.

Demographics

There were 208 questionnaires mailed to the participants. The criterion for selection was K-5 elementary teachers who participated in the IFI. Of the 208 mailed questionnaires, seven were returned as undeliverable. Of the remaining 201, a return rate of 66% was achieved with 132 returned questionnaires.

Also of value is a breakdown of the respondents according to their date of attendance for the intervention, the ASSET Institute for Inquiry (IFI). This information is needed to analyze change over time. At this juncture, the data is presented to establish a
context, the typical respondent. Table 1 delineates the responses to the questionnaire according to attendance date. There was a 100% response to this question.

Table 1

Attendance to the IFI Identified by Frequency and Percentage of Respondents

<table>
<thead>
<tr>
<th>IFI Session</th>
<th>f</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall 2000</td>
<td>16</td>
<td>12.1</td>
</tr>
<tr>
<td>Winter 2001</td>
<td>12</td>
<td>9.1</td>
</tr>
<tr>
<td>Spring 2001</td>
<td>1</td>
<td>.8</td>
</tr>
<tr>
<td>Summer 2001</td>
<td>10</td>
<td>7.6</td>
</tr>
<tr>
<td>Fall 2001</td>
<td>13</td>
<td>9.8</td>
</tr>
<tr>
<td>Winter 2002</td>
<td>16</td>
<td>12.1</td>
</tr>
<tr>
<td>Spring 2002</td>
<td>13</td>
<td>9.8</td>
</tr>
<tr>
<td>Summer 2002</td>
<td>8</td>
<td>6.1</td>
</tr>
<tr>
<td>Fall 2002</td>
<td>14</td>
<td>10.6</td>
</tr>
<tr>
<td>Winter 2003</td>
<td>14</td>
<td>10.6</td>
</tr>
<tr>
<td>Spring 2003</td>
<td>15</td>
<td>11.4</td>
</tr>
</tbody>
</table>

Of the 132 responses, the distribution of the respondents ranged from one representative from the Spring 2001 IFI to sixteen representatives from the Fall 2000 and Winter 2002 IFIs. Within each IFI, the greater the number of attendees for a session the stronger the reliability and validity in the analysis of change over time demonstrated in the significance from the t test.
Table 2 displays the breakdown of respondents in kindergarten to fifth grades. The value in this information is in the demonstration of representation from the six grade levels. This question had a response rate of 84.1%.

Table 2

<table>
<thead>
<tr>
<th>Grade Level</th>
<th>f</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kindergarten</td>
<td>9</td>
<td>7.9</td>
</tr>
<tr>
<td>First</td>
<td>19</td>
<td>16.7</td>
</tr>
<tr>
<td>Second</td>
<td>25</td>
<td>21.9</td>
</tr>
<tr>
<td>Third</td>
<td>21</td>
<td>18.4</td>
</tr>
<tr>
<td>Fourth</td>
<td>25</td>
<td>21.9</td>
</tr>
<tr>
<td>Fifth</td>
<td>15</td>
<td>13.2</td>
</tr>
</tbody>
</table>

From the 132 respondents a breakdown reveals there is representation from the six grade levels pertinent to this study.

Table 3 represents the number of science modules used by the respondents during an academic year. There were 120 responses to this question. Sixty percent incorporate three modules into their science curriculum during an academic year.
Table 3

Module Use Identified by Frequency and Percentage of Respondents

<table>
<thead>
<tr>
<th>Modules</th>
<th>$f$</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>One</td>
<td>3</td>
<td>2.3</td>
</tr>
<tr>
<td>Two</td>
<td>31</td>
<td>25.8</td>
</tr>
<tr>
<td>Three</td>
<td>72</td>
<td>60.0</td>
</tr>
<tr>
<td>Four</td>
<td>14</td>
<td>11.7</td>
</tr>
</tbody>
</table>

Table 4 depicts the number of weeks a science unit is utilized in a K-5 classroom. The higher frequencies illustrate that the use varies between six or nine weeks. Of the 125 responses to this question 19% indicated six weeks for a science unit and 28% indicated nine weeks. The range of use was one week to ten weeks.

Table 4

Length in Weeks Science Unit/Module Lasts – Frequency and Percentage of Respondents

<table>
<thead>
<tr>
<th>Weeks</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>$f$</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>8</td>
<td>11</td>
<td>25</td>
<td>6</td>
<td>14</td>
<td>37</td>
<td>16</td>
</tr>
<tr>
<td>%</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>8</td>
<td>19</td>
<td>5</td>
<td>11</td>
<td>28</td>
<td>12</td>
</tr>
</tbody>
</table>

Note: $N = 125$

Using a crosstab calculation of frequencies, Table 5 depicts the number of years the respondents have been using science modules against the number of minutes a typical
science lesson lasts. The typical length of minutes was between 31-40 and 41-50. The
typical respondent has been using the science modules for five or more years.

Table 5

| Years Using Modules to Length of Science Lesson in Minutes |
|-----------------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
|                             | 1  2  3  4  5     | Total             |
| 11-20 Minutes               | 0  1  1  0  0     | 2                 |
| 21-30 Minutes               | 0  1  3  2  8     | 14                |
| 31-40 Minutes               | 2  5  11  5  19   | 42                |
| 41-50 Minutes               | 1  3  6  8  26    | 44                |
| 51-60 Minutes               | 0  3  2  1  9     | 19                |
| 61-70 Minutes               | 0  0  0  0  2     | 2                 |
| 71-80 Minutes               | 0  0  0  0  2     | 2                 |
| Total                       | 3  13  23  16  66 | 121               |

Table 6 is a crosstab of the rating of the IFI and a self-reported impact the IFI had
upon the respondent’s teaching of science. The response rate was 123 of the 132 returned
questionnaires, or 93.2%. The respondents were asked to rate the IFI (i.e., Question 10)
on a scale of one to five, poor to excellent, respectively. Question 11 asked the
respondent to indicate using a scale of one to five, none to a great deal, to state how much
of an impact the IFI had on their teaching of science.
### Table 6

Crosstab of Impact on Teaching of Science with Rating of the IFI

<table>
<thead>
<tr>
<th>Impact on Teaching of Science</th>
<th>Rating of the IFI</th>
<th>Some</th>
<th>Neutral</th>
<th>A lot</th>
<th>A great deal</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor</td>
<td>Poor</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Fair</td>
<td>Fair</td>
<td>4</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>Good</td>
<td>Good</td>
<td>13</td>
<td>7</td>
<td>2</td>
<td>0</td>
<td>22</td>
</tr>
<tr>
<td>Very good</td>
<td>Very good</td>
<td>9</td>
<td>5</td>
<td>37</td>
<td>3</td>
<td>54</td>
</tr>
<tr>
<td>Excellent</td>
<td>Excellent</td>
<td>2</td>
<td>1</td>
<td>15</td>
<td>23</td>
<td>41</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>Total</strong></td>
<td>29</td>
<td>14</td>
<td>54</td>
<td>26</td>
<td>123</td>
</tr>
</tbody>
</table>

Note: The response *none* was not selected for the question 11 which addresses the impact of the IFI.

When the participants rated the IFI, they responded the IFI was very good (*n* = 54) or excellent (*n* = 41). When the respondents who rated the IFI as very good are disaggregated against the question pertaining to impact upon their teaching of science they reveal there was a lot of impact on their pedagogical practices as opposed to the highest rating, a great deal. When the 41 respondents who rated the IFI as excellent are disaggregated, 15 selected a lot and 23 selected a great deal, with regard to the impact on their pedagogical practices for teaching science. These numbers indicate there is a statistical relationship between liking the IFI and an impact on translation to practice.

In summary, the most common response to the questionnaire was:

- Represents attendance in all of the eleven IFIs, noting that Spring 2001 has one representative;
• Represents the spectrum of kindergarten to fifth classrooms;
• Utilizes three modules for their science curriculum
• Uses a module, or concept unit, as either six or nine week unit;
• Has been teaching science with modules for three, four, or five years;
• Science instruction ranges from 31-40 minutes to 41-50 minutes for three lessons per week;
• Rates the IFI as very good or excellent; and
• Indicates the IFI has a lot of impact upon their teaching of science.

Analysis of Research Questions

The first research question asks the extent to which the IFI impacts the use of curriculum relating to the teaching of science. The analysis has two components; the first component relates frequency and the mean scores for before and after the intervention. The second component is a comparison of paired means to indicate change in use.

Table 7, which answers research question one, displays data from survey questions six and nineteen. These two questions ask the respondent to report their practice prior to the intervention and since the intervention. Each question is divided into eighteen subsets asking for responses using a Likert scale. The options were 1 never, 2 rarely, 3 occasionally, 4 frequently, and 5 always. Table 7 indicates the mean, standard deviation, and difference between the means. These numbers are the before and after sample responses for the eighteen items when comparing questions six and nineteen. The subset items listed in Table 6 are a compilation of the two items from questions six and nineteen.
The question addressed by Table 7 represents the first lens, curriculum, which is the use of new instructional materials and the related practice (Fullan, 2001). There were eighteen sub-questions repeated looking for a change in practice in the use of curriculum as previously defined. When a difference is determined between the before mean and the after the intervention mean, fourteen of the subset items have a mean increase ranging from +0.1 to +1.3. The mean increase demonstrates the participants reported a shift in their methods and strategies for teaching science. This shift is represented in the mean responses ranging from a rarely to frequently.
<table>
<thead>
<tr>
<th>Question Subset</th>
<th>Before Intervention</th>
<th>After Intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$M$</td>
<td>$SD$</td>
</tr>
<tr>
<td>Used modules for basis of lessons</td>
<td>4.3</td>
<td>.9</td>
</tr>
<tr>
<td>Utilized cooperative grouping</td>
<td>4.2</td>
<td>.7</td>
</tr>
<tr>
<td>Used textbooks primary source</td>
<td>2.2</td>
<td>1.1</td>
</tr>
<tr>
<td>Used non-textbooks materials</td>
<td>3.0</td>
<td>.7</td>
</tr>
<tr>
<td>Utilized textbooks/workheets</td>
<td>2.8</td>
<td>1.0</td>
</tr>
<tr>
<td>Utilized hands-on activities</td>
<td>4.0</td>
<td>.9</td>
</tr>
<tr>
<td>Require following specific instructions</td>
<td>3.9</td>
<td>.8</td>
</tr>
<tr>
<td>Students designed investigations</td>
<td>2.1</td>
<td>1.0</td>
</tr>
<tr>
<td>Used models or simulations</td>
<td>2.8</td>
<td>1.0</td>
</tr>
<tr>
<td>Class work extends week or more</td>
<td>2.5</td>
<td>1.0</td>
</tr>
<tr>
<td>Students participate in field work</td>
<td>2.2</td>
<td>.9</td>
</tr>
<tr>
<td>Used reflection notebook/journal</td>
<td>2.9</td>
<td>1.1</td>
</tr>
<tr>
<td>Incorporated math to problem solve</td>
<td>2.8</td>
<td>.9</td>
</tr>
<tr>
<td>Incorporated computers</td>
<td>2.2</td>
<td>1.0</td>
</tr>
<tr>
<td>Incorporated portfolios</td>
<td>2.2</td>
<td>1.1</td>
</tr>
<tr>
<td>Utilized short-answer tests</td>
<td>2.9</td>
<td>1.2</td>
</tr>
<tr>
<td>Utilized open-ended response tests</td>
<td>2.6</td>
<td>1.1</td>
</tr>
<tr>
<td>Utilized performance task assessments</td>
<td>2.7</td>
<td>1.0</td>
</tr>
</tbody>
</table>
There were four items from the subset that demonstrate a difference in means in a negative direction. The four items reflect use of textbooks as the primary vehicle for learning about science concepts, use of worksheets to answer textbook information, requiring students to follow specific instructions, and use of a linear approach with assessment. These four items are reflective of practices in teaching science that are counterintuitive to the teaching of science through inquiry. Further statistical analysis occurs with subsequent research questions.

The second part of research question one is to determine a statistical significance between the before and after the intervention. Table 8 depicts the results of the Paired Samples $t$ test which indicates statistical significance between the two means.
Table 8

Curriculum Lens: Pairing of the Items in Questions 6 and 19

<table>
<thead>
<tr>
<th>Paired Subsets</th>
<th>$\Delta M$</th>
<th>$N$</th>
<th>$SD$</th>
<th>$t$</th>
<th>$df$</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Used modules for basis of lessons</td>
<td>.1</td>
<td>117</td>
<td>.9</td>
<td>1.5</td>
<td>116</td>
<td>.132</td>
</tr>
<tr>
<td>Utilized cooperative grouping</td>
<td>.3</td>
<td>120</td>
<td>.7</td>
<td>4.8</td>
<td>119</td>
<td>.000</td>
</tr>
<tr>
<td>Used textbooks primary source</td>
<td>-.3</td>
<td>121</td>
<td>.9</td>
<td>-4.2</td>
<td>120</td>
<td>.000</td>
</tr>
<tr>
<td>Used non-textbooks materials</td>
<td>.3</td>
<td>121</td>
<td>.8</td>
<td>3.8</td>
<td>120</td>
<td>.000</td>
</tr>
<tr>
<td>Utilized textbooks/worksheets</td>
<td>-.6</td>
<td>120</td>
<td>.9</td>
<td>-6.7</td>
<td>119</td>
<td>.000</td>
</tr>
<tr>
<td>Utilized hands-on activities</td>
<td>.5</td>
<td>121</td>
<td>.9</td>
<td>5.9</td>
<td>120</td>
<td>.000</td>
</tr>
<tr>
<td>Require following specific instructions</td>
<td>-.4</td>
<td>121</td>
<td>1.1</td>
<td>-4.3</td>
<td>120</td>
<td>.000</td>
</tr>
<tr>
<td>Students designed investigations</td>
<td>1.2</td>
<td>121</td>
<td>.9</td>
<td>14.8</td>
<td>120</td>
<td>.000</td>
</tr>
<tr>
<td>Used models or simulations</td>
<td>.5</td>
<td>120</td>
<td>1.0</td>
<td>5.3</td>
<td>119</td>
<td>.000</td>
</tr>
<tr>
<td>Class work extends week or more</td>
<td>.7</td>
<td>121</td>
<td>1.0</td>
<td>8.0</td>
<td>120</td>
<td>.000</td>
</tr>
<tr>
<td>Students participate in field work</td>
<td>.5</td>
<td>121</td>
<td>.9</td>
<td>6.8</td>
<td>120</td>
<td>.000</td>
</tr>
<tr>
<td>Used reflection notebook/journal</td>
<td>1.2</td>
<td>121</td>
<td>1.3</td>
<td>10.8</td>
<td>120</td>
<td>.000</td>
</tr>
<tr>
<td>Incorporated math to problem solve</td>
<td>.7</td>
<td>119</td>
<td>.8</td>
<td>9.1</td>
<td>118</td>
<td>.000</td>
</tr>
<tr>
<td>Incorporated computers</td>
<td>.6</td>
<td>121</td>
<td>.9</td>
<td>7.8</td>
<td>120</td>
<td>.000</td>
</tr>
<tr>
<td>Incorporated portfolios</td>
<td>.6</td>
<td>121</td>
<td>1.0</td>
<td>6.5</td>
<td>120</td>
<td>.000</td>
</tr>
<tr>
<td>Utilized short-answer tests</td>
<td>-.5</td>
<td>120</td>
<td>.9</td>
<td>-5.7</td>
<td>119</td>
<td>.000</td>
</tr>
<tr>
<td>Utilized open-ended response tests</td>
<td>.6</td>
<td>119</td>
<td>.8</td>
<td>7.8</td>
<td>118</td>
<td>.000</td>
</tr>
<tr>
<td>Utilized performance task assessments</td>
<td>1.2</td>
<td>120</td>
<td>2.9</td>
<td>4.7</td>
<td>119</td>
<td>.000</td>
</tr>
</tbody>
</table>

$p < .05$ was used for statistical tests.
The mean ($\Delta M$) is the difference between the before and the after groups reported in Table 6.

Examining the data in Table 8 it can be stated that those participants who had experienced the IFI display a statistically significant increase of behavior in the incorporation of those recommended strategies and methodologies, except for the first paired samples. The first before and after subset, queried the respondents about the use of modules as the basis for their science lessons.

The first paired sample does not indicate a significant change in behavior. The low change, ($\Delta M = .1$) in the use of modules, is significant when viewed through the data gathered through question seven. Here the respondent is asked the number of years they have been using science modules for their instruction. The median score is five or more years. The population for this research spanned almost three years. This indicates the behavior inherent in the first pair samples could have been practiced prior to attending the IFI. When this first subset is disaggregated against the number of years which the respondent has been using science modules, the responses of the groups cluster with either a 4 (*Frequently*) or a 5 (*Always*). Table 9 is the disaggregated information relating the number of years the respondent has been using science modules as their curriculum.
Table 9

Module Use: Frequency of Use against the Number of Years Using

<table>
<thead>
<tr>
<th>Rating of Use</th>
<th>First B</th>
<th>First A</th>
<th>Second B</th>
<th>Second A</th>
<th>Third B</th>
<th>Third A</th>
<th>Fourth B</th>
<th>Fourth A</th>
<th>Fifth or more B</th>
<th>Fifth or more A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Never</td>
<td>1</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Rarely</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Occasionally</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>5</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Frequently</td>
<td>1</td>
<td>0</td>
<td>4</td>
<td>6</td>
<td>9</td>
<td>15</td>
<td>8</td>
<td>5</td>
<td>23</td>
<td>28</td>
</tr>
<tr>
<td>Always</td>
<td>1</td>
<td>2</td>
<td>6</td>
<td>8</td>
<td>9</td>
<td>7</td>
<td>6</td>
<td>8</td>
<td>38</td>
<td>33</td>
</tr>
</tbody>
</table>

Note: B represents before the intervention and A represents after the intervention.

Research question two relates to the second lens that is essential for change in instruction to occur. This second lens is a reflection of teaching practices. Table 10 and Table 11 are a compilation of data from question one and eighteen. Question one asks for reflection upon teaching before and since the IFI. The subsets are the same for both questions. For this table the data is disaggregated into the NSES teaching standards (NRC, 2000) which encompass changes in emphasis (see Appendix B). The NSES recommended standards for behavior for science instruction are parallel as to the less emphasized behavior with the more emphasized behaviors. NSES identified eight behaviors of science instruction that are systemic and teachers should use less. In counter to the identified behaviors that should be practiced less, the NSES identified eight behaviors that should be practiced. When questions one and eighteen were constructed these two groups were mixed. For the tables 10, 11, 12, and 13, the less and more
emphasized behaviors were returned to their original groupings. In addition, the original terminology is used in the tables.

Table 10 exhibits a change in the frequency of those identified behaviors that the NSES recommends teachers of science emphasize less in their instructional practices. The indication that a change in behavior is occurring is reflection when a comparison of two means for a given behavior moved down. A comparison of those behaviors the NSES recommends have less emphasis in classrooms, the reported before and after means indicate movement away from the eight identified behaviors.

The before means range from 3.0 to 4.4, translating on the Likert scale as a 3, occasionally, and 4 frequently. The after means range from 2.7 to 4.1, translating on the Likert scales as 2, rarely, 3, occasionally, and 4, frequently. The only category that did not move down was support of competition. It stayed as a 3, an occasionally used behavior.

When this data is compared to Table 11, a change is seen in the frequency of those behaviors that the NSES recommends teachers of science strive to incorporate into their instructional practices and philosophies. A comparison of all the means in Table 11 indicates a movement toward the recommended standards for science instruction. The before means range from 2.9 to 4.2. The after means range from 3.5 to 4.4. The data exhibits a movement toward the recommended behaviors in all eight categories.

Two categories worth a moment of focus are the category of getting students in active and extended scientific inquiry and the category of the teacher focusing on student understanding of knowledge and processes. The category for having students be engaged in active and extended inquiry increased from 2.6, rarely, to 3.8, occasionally, reflecting a
mean gain of +1.2. The category reflective of a behavior that is a focus on student understanding increased from 3.1, occasionally, to 4.2, frequently, reflecting a mean gain of +1.1.

Table 10
Teaching Practice: Frequency for the Less Emphasized Teaching Practices

<table>
<thead>
<tr>
<th>Less Emphasis Standard</th>
<th>Before M</th>
<th>SD</th>
<th>N</th>
<th>After M</th>
<th>SD</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treating all students alike and responding to the group as a whole</td>
<td>3.6</td>
<td>1.0</td>
<td>123</td>
<td>2.9</td>
<td>1.1</td>
<td>121</td>
</tr>
<tr>
<td>Rigidly following curriculum</td>
<td>4.0</td>
<td>0.8</td>
<td>122</td>
<td>3.5</td>
<td>0.8</td>
<td>122</td>
</tr>
<tr>
<td>Focusing on student acquisition of knowledge</td>
<td>3.9</td>
<td>0.8</td>
<td>124</td>
<td>3.8</td>
<td>0.9</td>
<td>122</td>
</tr>
<tr>
<td>Presenting scientific knowledge through lecture, text and demonstration</td>
<td>3.6</td>
<td>1.1</td>
<td>124</td>
<td>2.9</td>
<td>0.9</td>
<td>122</td>
</tr>
<tr>
<td>Testing students for factual information at the end of each chapter</td>
<td>3.5</td>
<td>1.3</td>
<td>123</td>
<td>2.7</td>
<td>1.2</td>
<td>123</td>
</tr>
<tr>
<td>Maintaining responsibility and authority</td>
<td>4.4</td>
<td>0.7</td>
<td>124</td>
<td>4.1</td>
<td>0.8</td>
<td>121</td>
</tr>
<tr>
<td>Supporting competition</td>
<td>3.0</td>
<td>1.0</td>
<td>124</td>
<td>3.2</td>
<td>1.2</td>
<td>123</td>
</tr>
<tr>
<td>Working alone</td>
<td>3.9</td>
<td>0.9</td>
<td>124</td>
<td>3.3</td>
<td>1.0</td>
<td>121</td>
</tr>
</tbody>
</table>

Note: The less emphasis standards relate to questions one and eighteen in this procedure: 1b,18b is the first listed standard, etc.; 1i,18i; 1l,18l; 1o,18o; 1e,18e; 1k,18k; 1j,18j; 1n,18n.
Table 11

Teaching Practice: Frequency for the More Emphasized Teaching Practices

<table>
<thead>
<tr>
<th>More Emphasis Standard</th>
<th>Before</th>
<th></th>
<th>After</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>N</td>
<td>M</td>
</tr>
<tr>
<td>Understanding and responding to individual student’s interests, strengths, experiences and needs</td>
<td>3.6</td>
<td>0.9</td>
<td>122</td>
<td>4.4</td>
</tr>
<tr>
<td>Selecting and adapting curriculum</td>
<td>3.3</td>
<td>1.0</td>
<td>124</td>
<td>3.8</td>
</tr>
<tr>
<td>Focusing on student understanding and use of scientific knowledge, ideas and inquiry processes</td>
<td>3.1</td>
<td>0.9</td>
<td>124</td>
<td>4.2</td>
</tr>
<tr>
<td>Getting students in active and extended scientific inquiry</td>
<td>2.6</td>
<td>1.0</td>
<td>124</td>
<td>3.8</td>
</tr>
<tr>
<td>Continuously assessing student understanding</td>
<td>3.6</td>
<td>1.0</td>
<td>123</td>
<td>4.3</td>
</tr>
<tr>
<td>Sharing responsibility for learning with students</td>
<td>3.3</td>
<td>1.1</td>
<td>124</td>
<td>4.2</td>
</tr>
<tr>
<td>Supporting a classroom community with cooperation, shared responsibility and respect</td>
<td>4.2</td>
<td>0.9</td>
<td>124</td>
<td>4.7</td>
</tr>
<tr>
<td>Working with other teachers to enhance the science program</td>
<td>2.9</td>
<td>1.0</td>
<td>124</td>
<td>3.5</td>
</tr>
</tbody>
</table>

Note: The less emphasis standards relate to questions one and eighteen in this procedure: 1h,18h is the first listed standard, etc.; 1p,18p; 1m,18m; 1c,18c; 1f,18f; 1d,18d; 1g,18g; 1a,18a.
Table 12 and Table 13 are the Paired Samples $t$ Test. Table 12 is a comparison of the before and after for each of the less emphasis categories. Table 13 is a comparison of the before and after for each of the more emphasis categories.

Table 12

Teaching Practice: Before and After $t$ Test – Less Emphasized Standard

<table>
<thead>
<tr>
<th>Less Emphasis Standard</th>
<th>$M$</th>
<th>$N$</th>
<th>$SD$</th>
<th>$t$</th>
<th>$df$</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treating all students alike and responding to the group as a whole</td>
<td>-0.7</td>
<td>120</td>
<td>1.0</td>
<td>-7.4</td>
<td>119</td>
<td>.000</td>
</tr>
<tr>
<td>Rigidly following curriculum</td>
<td>-0.5</td>
<td>121</td>
<td>0.9</td>
<td>-6.0</td>
<td>120</td>
<td>.000</td>
</tr>
<tr>
<td>Focusing on student acquisition of knowledge</td>
<td>-0.2</td>
<td>122</td>
<td>1.0</td>
<td>-1.3</td>
<td>120</td>
<td>.188</td>
</tr>
<tr>
<td>Presenting scientific knowledge through lecture, text and demonstration</td>
<td>-0.8</td>
<td>122</td>
<td>1.2</td>
<td>-7.5</td>
<td>121</td>
<td>.000</td>
</tr>
<tr>
<td>Testing students for factual information at the end of each chapter</td>
<td>-0.8</td>
<td>122</td>
<td>1.2</td>
<td>-7.6</td>
<td>121</td>
<td>.000</td>
</tr>
<tr>
<td>Maintaining responsibility and authority</td>
<td>-0.3</td>
<td>121</td>
<td>0.9</td>
<td>-3.7</td>
<td>120</td>
<td>.000</td>
</tr>
<tr>
<td>Supporting competition</td>
<td>0.2</td>
<td>123</td>
<td>1.0</td>
<td>2.1</td>
<td>122</td>
<td>.036</td>
</tr>
<tr>
<td>Working alone</td>
<td>-0.6</td>
<td>121</td>
<td>1.1</td>
<td>-5.8</td>
<td>120</td>
<td>.000</td>
</tr>
</tbody>
</table>

Note: $M$ is the difference of before and after means.

Table 12 exhibits a negative direction for each mean for each category, except for supporting competition, but it was still statistically significant with $t(122) = 2.1, p = .036$ of not happening by chance. This falls below the significance rating of $p \leq 0.05$. The category, focusing on student acquisition of knowledge, depicts no statistical significance $p = .188$. 
The negative direction for the mean is what is expected. The data in Table 12 supports the data in Table 10. The Paired Samples $t$ Test offers further support with seven of the eight categories having a significance level of .000 (2-tailed).

Table 13
Teaching Practice: Before and After $t$ Test – More Emphasized Standard

<table>
<thead>
<tr>
<th>More Emphasis Standard</th>
<th>$M$</th>
<th>$N$</th>
<th>$SD$</th>
<th>$t$</th>
<th>$df$</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Understanding and responding to individual student’s interests, strengths, experiences and needs</td>
<td>0.8</td>
<td>121</td>
<td>0.9</td>
<td>9.2</td>
<td>120</td>
<td>.000</td>
</tr>
<tr>
<td>Selecting and adapting curriculum</td>
<td>0.6</td>
<td>122</td>
<td>1.0</td>
<td>6.2</td>
<td>121</td>
<td>.000</td>
</tr>
<tr>
<td>Focusing on student understanding and use of scientific knowledge, ideas and inquiry processes</td>
<td>1.1</td>
<td>123</td>
<td>1.0</td>
<td>12.6</td>
<td>122</td>
<td>.000</td>
</tr>
<tr>
<td>Getting students in active and extended inquiry</td>
<td>1.1</td>
<td>123</td>
<td>1.0</td>
<td>12.0</td>
<td>122</td>
<td>.000</td>
</tr>
<tr>
<td>Continuously assessing student understanding</td>
<td>0.7</td>
<td>122</td>
<td>1.0</td>
<td>8.2</td>
<td>121</td>
<td>.000</td>
</tr>
<tr>
<td>Sharing responsibility for learning with students</td>
<td>0.9</td>
<td>123</td>
<td>1.0</td>
<td>9.5</td>
<td>122</td>
<td>.000</td>
</tr>
<tr>
<td>Supporting a classroom community with cooperation, shared responsibility and respect</td>
<td>0.5</td>
<td>122</td>
<td>1.0</td>
<td>5.9</td>
<td>121</td>
<td>.000</td>
</tr>
<tr>
<td>Working with other teachers to enhance the science program</td>
<td>0.6</td>
<td>123</td>
<td>1.1</td>
<td>5.9</td>
<td>122</td>
<td>.000</td>
</tr>
</tbody>
</table>

Note: $M$ is the difference of before and after means

Table 13 exhibits a positive direction for each of the eight categories reflecting movement of the more emphasized behaviors. The range of increase for the mean is 0.5
to 1.1. The Paired Samples $t$ Test depicts a statistical significance for all eight categories with a significance of .000 (2-tailed) that the behaviors of the respondents display a sign of increase in behavior occurring on the NSES indicators.

The third hypothesis questions whether the data will reveal a statistically significant relationship between the frequency of use of inquiry as a philosophy in practice and the IFI. Question twenty is the data port for this information. The five items within question twenty are the indicators of inquiry in a classroom setting and are from the NSES inquiry standard (NRC, 2000). The reported behavior by the respondents indicates a frequent use of the indicators of the practice of teaching science through inquiry in their classroom practice.
Table 14

Teaching Philosophy as Practice: Frequency of Response

<table>
<thead>
<tr>
<th>Inquiry in Practice</th>
<th>Never</th>
<th>Rarely</th>
<th>Occasionally</th>
<th>Frequently</th>
<th>Always</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students engaged in meaningful and relevant scientific questions ($M = 4.1$)</td>
<td>0</td>
<td>2</td>
<td>16</td>
<td>77</td>
<td>28</td>
<td>123</td>
</tr>
<tr>
<td>Student evidence used to develop explanation for the scientific question ($M = 3.7$)</td>
<td>0</td>
<td>6</td>
<td>42</td>
<td>64</td>
<td>11</td>
<td>123</td>
</tr>
<tr>
<td>Student formulates explanation based on their evidence ($M = 3.9$)</td>
<td>1</td>
<td>5</td>
<td>21</td>
<td>70</td>
<td>26</td>
<td>123</td>
</tr>
<tr>
<td>Student evaluates explanation consistent with current science knowledge ($M = 3.6$)</td>
<td>3</td>
<td>9</td>
<td>35</td>
<td>61</td>
<td>15</td>
<td>123</td>
</tr>
<tr>
<td>Student communicates with justified explanation ($M = 4.0$)</td>
<td>2</td>
<td>3</td>
<td>23</td>
<td>65</td>
<td>30</td>
<td>123</td>
</tr>
</tbody>
</table>

Note: $M$ for each indicator of practice is in parentheses.

Research question number four asks if there is a statistically significant relationship between years teaching and the use of inquiry. Table 15 is a bivariate correlation, i.e., the Pearson $r$, of the years the respondents have taught to the indicators of inquiry in practice identified by the NSES. The Pearson correlation coefficient for all five behaviors indicates there is statistical significance as indicated by $p \leq .05$ value. This data is supported with an examination of the correlations, or $r$. All correlations are close to the 0.0 indicating no correlation.
Table 15

Teaching Practice: Years Teaching to Inquiry in Practice

<table>
<thead>
<tr>
<th>Inquiry in Practice</th>
<th>N</th>
<th>r</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students engaged in meaningfully relevant scientific questions</td>
<td>123</td>
<td>-.145</td>
<td>.109</td>
</tr>
<tr>
<td>Students use evidence to develop explanations of scientific questions</td>
<td>123</td>
<td>-.025</td>
<td>.786</td>
</tr>
<tr>
<td>Students formulate questions based on evidence</td>
<td>123</td>
<td>.039</td>
<td>.666</td>
</tr>
<tr>
<td>Students evaluate their explanations consistent with current science knowledge</td>
<td>123</td>
<td>.146</td>
<td>.108</td>
</tr>
<tr>
<td>Students communicate and justify their explanations</td>
<td>123</td>
<td>-.005</td>
<td>.958</td>
</tr>
</tbody>
</table>

Table 16 depicts the most frequent indicator of use for the five indicators of inquiry in practice in classroom settings. These are disaggregated against the number of years the respondent has been teaching as of the year they completed the questionnaire. The mean for the sample population is included to demonstrate the strength represented by the number of respondents. The percentage is of the sampled population (n).
Table 16

Teaching Practice: Years Teaching to Inquiry in Practice

<table>
<thead>
<tr>
<th>Years Teaching</th>
<th>Students engage in meaningfully relevant scientific questions</th>
<th>Students use evidence to develop explanations of scientific questions</th>
<th>Students formulate questions based on evidence</th>
<th>Students evaluate their explanations consistent with current science knowledge</th>
<th>Students communicate and justify their explanations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>f</td>
<td>%</td>
<td>M</td>
<td>f</td>
</tr>
<tr>
<td>0-2</td>
<td>4.3</td>
<td>3</td>
<td>50</td>
<td>4.0</td>
<td>4</td>
</tr>
<tr>
<td>3-5</td>
<td>3.9</td>
<td>9</td>
<td>56</td>
<td>3.4</td>
<td>8</td>
</tr>
<tr>
<td>6-10</td>
<td>4.3</td>
<td>15</td>
<td>54</td>
<td>3.8</td>
<td>13</td>
</tr>
<tr>
<td>11-15</td>
<td>3.9</td>
<td>12</td>
<td>67</td>
<td>3.5</td>
<td>7*</td>
</tr>
<tr>
<td>16-20</td>
<td>4.3</td>
<td>7</td>
<td>70</td>
<td>3.9</td>
<td>9</td>
</tr>
<tr>
<td>21-25</td>
<td>3.8</td>
<td>10</td>
<td>63</td>
<td>3.7</td>
<td>8</td>
</tr>
<tr>
<td>26+</td>
<td>4.0</td>
<td>22</td>
<td>76</td>
<td>3.6</td>
<td>15</td>
</tr>
</tbody>
</table>

Note: The f value is the most frequent answer indicated Likert response. * Indicates a tie between this score and the immediately following. The one closest to the mean was used in this table.

The general response to the indicators is 4, frequently. This data is self-reported behavior, which states that the respondent’s usual method for teaching science frequently has their students demonstrating the five the identified behaviors.

The fifth research question asks if there exists a statistically significant relationship between the indicators of use of inquiry in practice and the use of an ASSET
resource teacher. Table 17 is a Pearson \( r \) correlation of the five indicators of inquiry in practice and question nine. Question nine has three components which asked the respondent to indicate the frequency of interaction with the resource teacher using a Likert scale. The scale is 1 – never, 2 – rarely, 3 – occasionally, 4 – frequently, and 5 – always. In addition each was described in the questionnaire. The frequency was identified as 1 – never – no visits, 2 – rarely – one visit, 3 – occasionally – two visits, 4 – frequently – three or four visits, and 5 – always – five or more visits.

Within question nine there are three questions relating to time spent with their resource teacher. The time was referenced by behaviors of coaching, general visiting, and assistance with translation of practice. Each of the three was compared individually to the five indicators. The findings are Table 17.
Table 17

Resource Teacher Correlated to the Behaviors of Inquiry in the Classroom

<table>
<thead>
<tr>
<th>Inquiry in Practice</th>
<th>Coached by RT</th>
<th>Visited by RT</th>
<th>Assisted by RT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students engaged in meaningfully relevant scientific questions</td>
<td>-.021</td>
<td>-.005</td>
<td>.005</td>
</tr>
<tr>
<td>Students use evidence to develop explanations of scientific questions</td>
<td>.002</td>
<td>-.097</td>
<td>-.047</td>
</tr>
<tr>
<td>Students formulate questions based on evidence</td>
<td>-.016</td>
<td>-.061</td>
<td>-.057</td>
</tr>
<tr>
<td>Students evaluate their explanations consistent with current science knowledge</td>
<td>.099</td>
<td>.008</td>
<td>.030</td>
</tr>
<tr>
<td>Students communicate and justify their explanations</td>
<td>.037</td>
<td>-.048</td>
<td>.005</td>
</tr>
</tbody>
</table>

Note: $M = 122$. The significance level was set at $p \leq 0.05$.

The Pearson $r$ correlation of the assistance by an ASSET resource teacher (RT) and the behaviors of teachers having students utilize the process of inquiry indicates there is no statistical significance between the RT and the practice of inquiry in K-5 classrooms. The Pearson $r$ ranges from -.097 to +.099 supporting the lack of statistical significance. The value, $p \leq .05$, has a range from .280 to .979, all above the statistically significant confidence level.
Table 18 depicts the frequency of responses to the utilization of the resource teacher. The data indicates the amount of time the resource teacher worked with the IFI participant was reported as occasionally, or two visits. When the topic of the resource teacher coaching the participant was answered, the responses cluster around occasionally, rarely, and never. When the topic of the resource teacher visiting the IFI participant was presented, the responses cluster around one to four visits. When the topic of the resource teacher assisting the IFI participant with the translation of the theory of inquiry into classroom practice was asked, the responses were across the scale, none to more than five.

Table 18

<table>
<thead>
<tr>
<th>Frequency of Use</th>
<th>Coached by RT</th>
<th></th>
<th>Visited by RT</th>
<th></th>
<th>Assisted by RT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>f</td>
<td>SD</td>
<td>M</td>
<td>%</td>
<td>f</td>
</tr>
<tr>
<td>Never</td>
<td>31</td>
<td>1.2</td>
<td>2.3</td>
<td>24</td>
<td>16</td>
</tr>
<tr>
<td>Rarely</td>
<td>23</td>
<td>1.2</td>
<td>2.3</td>
<td>17</td>
<td>28</td>
</tr>
<tr>
<td>Occasionally</td>
<td>43</td>
<td>1.2</td>
<td>2.3</td>
<td>33</td>
<td>39</td>
</tr>
<tr>
<td>Frequently</td>
<td>17</td>
<td>1.2</td>
<td>2.3</td>
<td>13</td>
<td>28</td>
</tr>
<tr>
<td>Always</td>
<td>8</td>
<td>1.2</td>
<td>2.3</td>
<td>8</td>
<td>11</td>
</tr>
</tbody>
</table>

Research question six asks for a relationship between length of time between attending an IFI and the practice of teaching science through inquiry. Table 19 depicts the correlation of attendance with practicing inquiry in K-5 classrooms. The data indicates there is no statistical significance between the date the participant attended the IFI and the use of inquiry to teach science.
There were eleven IFIs from the fall of 2000 through the spring of 2003. From these eleven institutes the population for this research was garnered. Table 20 offers data indicating the mean response from each of the eleven IFI sessions conducted related to the five indicators of science inquiry being practiced in K-5 settings. The data indicates there is a frequent behavior by the respondent, which requires students to model inquiry in their science work.

Table 19

<table>
<thead>
<tr>
<th>Inquiry in Practice</th>
<th>N</th>
<th>r</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students engaged in meaningfully relevant scientific questions</td>
<td>123</td>
<td>.007</td>
<td>.940</td>
</tr>
<tr>
<td>Students use evidence to develop explanations of scientific questions</td>
<td>123</td>
<td>-.011</td>
<td>.905</td>
</tr>
<tr>
<td>Students formulate questions based on evidence</td>
<td>123</td>
<td>-.113</td>
<td>.212</td>
</tr>
<tr>
<td>Students evaluate their explanations consistent with current science knowledge</td>
<td>123</td>
<td>-.042</td>
<td>.642</td>
</tr>
<tr>
<td>Students communicate and justify their explanations</td>
<td>123</td>
<td>-.050</td>
<td>.581</td>
</tr>
</tbody>
</table>
### Table 20

**Teaching Practice: When Attended to Inquiry in Practice**

<table>
<thead>
<tr>
<th>Students engage in meaningfully relevant scientific questions</th>
<th>Students use evidence to develop explanations of scientific questions</th>
<th>Students formulate questions based on evidence</th>
<th>Students evaluate their explanations consistent with current science knowledge</th>
<th>Students communicate and justify their explanations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Years</strong></td>
<td><strong>Teaching</strong></td>
<td><strong>M</strong></td>
<td><strong>SD</strong></td>
<td><strong>M</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fall ’00</td>
<td>4.2</td>
<td>.56</td>
<td>4.0</td>
<td>.53</td>
</tr>
<tr>
<td>Winter ’01</td>
<td>3.9</td>
<td>.83</td>
<td>3.6</td>
<td>.81</td>
</tr>
<tr>
<td>Spring ’01</td>
<td>3.0</td>
<td>-</td>
<td>2.0</td>
<td>-</td>
</tr>
<tr>
<td>Summer ’01</td>
<td>4.2</td>
<td>.63</td>
<td>3.7</td>
<td>.82</td>
</tr>
<tr>
<td>Fall ’01</td>
<td>4.1</td>
<td>.51</td>
<td>3.4</td>
<td>.67</td>
</tr>
<tr>
<td>Winter ’02</td>
<td>3.9</td>
<td>.70</td>
<td>3.3</td>
<td>.72</td>
</tr>
<tr>
<td>Spring ’02</td>
<td>4.1</td>
<td>.67</td>
<td>3.8</td>
<td>.75</td>
</tr>
<tr>
<td>Summer ’02</td>
<td>3.8</td>
<td>1.20</td>
<td>3.3</td>
<td>.82</td>
</tr>
<tr>
<td>Fall ’02</td>
<td>4.2</td>
<td>.36</td>
<td>3.8</td>
<td>.58</td>
</tr>
<tr>
<td>Winter ’03</td>
<td>4.2</td>
<td>.73</td>
<td>3.6</td>
<td>.77</td>
</tr>
<tr>
<td>Spring ’03</td>
<td>4.0</td>
<td>.55</td>
<td>3.9</td>
<td>.53</td>
</tr>
</tbody>
</table>
Summary

The data that was analyzed in this chapter was derived from a population of K-5 teachers. These teachers attended the ASSET Institute for Inquiry between the fall of 2000 and the spring of 2003. There were 208 participants in the eleven IFIs. This researcher collected 132 returned questionnaires, a 66% rate of return. The data was used to answer the six research questions. The analysis of the data used descriptive, inferential, and correlational or associational statistics. The analysis began with demographic data to develop a portrait of the respondent. Following the demographic information, each of the six research questions was presented with data pertinent to that question. A discussion of these results is in chapter five.
CHAPTER 5

“I hear, and I forget. I see, and I remember. I do, and I understand.”

Chinese Proverb

DISCUSSION OF RESULTS

Overview

This chapter presents a discussion of the data analysis offered in Chapter Four. The discussion begins with an overview of the findings. Next, each research question is presented in context of the premise of this research, that on-going in-depth professional development that models the philosophy and methodologies indigenous to the teaching of science through inquiry can impact a change in the classroom practices of K-5 teachers. The discussion is presented through the three lenses of curriculum, instruction, and philosophy, as reviewed in the literature and developed as a model in Chapter Two.

Results

- There is a statistically significant relationship between the use of materials and the completion of the Institute for Inquiry.
- There is a statistically significant relationship between the completion of the IFI and a change in practice for teaching science through inquiry.
- There is a statistically significant relationship between the frequency of the practice of using inquiry and the IFI.
- There is not a statistically significant relationship between length of service teaching and the IFI.
• There is not a statistically significant relationship between the frequency the respondent utilized their resource teacher and the translation to practice of teaching science through inquiry.

• There is not a statistically significant relationship between the time interval of completion of the IFI and the practice of teaching science through inquiry.

The results of this research affirm the hypothesis that there is a statistically significant relationship between the intervention, the ASSET Institute for Inquiry, and a change in practice of teaching science through inquiry. From the data, participation in the IFI influences change in curriculum, instruction, and philosophy. This implies that professional development that is in-depth (Loucks-Horsley, Love, Stiles, Mundry, & Hewson, 2003; NRC, 1996, 2001; NSRC, 1997) can impact teaching practice. The data supports the concept of how professional development should be delivered as stated in the literature.

The results of this study demonstrate a relationship between the use of an inquiry-based hands-on science curriculum and the impact of the IFI in changing teaching practices. Change in how science is taught in elementary classrooms should be systemic (NSRC, 1997; Smith & O’Day, 1990). The systemic process requires a change from within the structure (Smith & O’Day, 1990) of pedagogical practices (DeBoer, 1991). The model presented in Chapter Two illustrates inquiry as the driver of this change as presented in Figure 2 (page 30). Inquiry would influence curriculum, instructional practices, and philosophy about educational process (Fullan, 2001). For the discussion of the findings set forth in Chapter Four, it is structured around the model of change and
Fullan’s three elements essential for change. These three elements will frame the discussion of the impact of an intervention such as the Institute for Inquiry and its impact upon teaching practices in K-5 classrooms. The discussion begins with curriculum.

Discussion

**Lens One: Curriculum of Inquiry**

Curriculum, the first lens, is the use of material and the related practices strategic for successful implementation (Fullan, 2001). The STC, FOSS, and Insights modules are the inquiry-based curriculum used by the respondents. With each module, the teacher has professional training pertinent to the use of the materials in the module, presented in the context of the concepts the materials are intended to develop.

The data from this research demonstrate an increase in the use of these modules as instructional materials and the use of the related strategic practices. Also the data indicate a use of the hands-on inquiry-based science as the primary science curriculum and the related instructional strategies, indicated in the increase of the number of modules used in a grade level during an academic year. This is supported in this research through the self-reported increase in those behaviors reflective of the practices for teaching science using hands-on quality materials to foster students doing what scientists do (Doris, 1991).

Though the data indicate minimal increase in the use of modules, this view is strengthened when viewed from the perspective that 32% of the participants in the IFI had been using modules for five or more years, which has some of the participants using modules two years before the first IFI was ever offered. Therefore, it could be expected
that the increase in use would be minimal. Further analysis of the data reveals an increase of those strategies and practices essential for teaching science through inquiry.

Teaching strategies relating to hands-on inquiry-based curriculum increased for those categories reflective of inquiry science (NRC, 1996, 2000). The respondents indicate they incorporate into their regular practice, strategies that are supportive of an inquiry-based curriculum designed to mirror methods and customs of scientists. The data establish a relationship between shifting from the use of science textbooks as the primary source for information toward a use of text materials as a resource. The data demonstrate an increase in having students design their own investigations and having those investigations extend beyond a lesson or week of lessons. This curriculum strategy increased from rarely being incorporated into practice to an occasional use. In using these curriculum strategies, the teachers, or respondents, are utilizing many of the recommended practices (AAAS, 1993) for creating an American workforce that is dedicated to life-long learning, problem solving, and learning collaboratively (Layman, 1996).

The data support a relationship between the teacher learning these skills through the intervention, the IFI, and those behaviors needing to be developed and practiced, which are inherent to the three goals for an American workforce. The reported information portrays the teachers using cooperative groupings because there was movement from frequent use to always using this method of grouping for instruction and learning. In addition, the analysis indicates an increase in problem solving skills that are essential for life-long learning, evidenced in students designing investigations and using
non-textbook material to build upon existing information to reflect and report out findings.

As the students use the materials to gather knowledge and understanding, the new knowledge is incorporated into solving their self-generated problem. Often the students work in groups to solve the problem which affords an opportunity to develop the social skills reflective of a collaborative approach to learning (Vygotsky, 1978). These two skills become part of their academic environment which was fostered, nurtured, and practiced across the science curriculum. It is in this across the board integration that a transfer to life-long learning begins to become ingrained.

The new behaviors being demonstrated and practiced by students require a new curriculum focus for assessment. The practice of using performance based assessment has a statistically significant increase demonstrated in the difference in means from before and after the intervention, +2.7 to +3.9. Performance based assessment requires the learner to demonstrate the internalized process of the learning they have traversed (Harlen, 2000; Piaget 1964, 1970). It is in this demonstration that the learner is assessed about the understanding. An increase in use of journals/notebooks and portfolios offer further support of change in those practices critical for development of life-long learning dispositions and attitudes; problem-solving practices required for a literate and contributing citizen; and those skills needed to work collaboratively with peers.

In addition, there is a decrease in those practices that are counter-intuitive to inquiry. There is a decrease in the practice of using worksheets which indicates less dependency of a right/wrong scenario. There is a decrease in use of short answer tests, textbooks, and the practice of rigid following of the textbook as the curriculum.
**Lens Two: Instruction of Inquiry**

In the National Science Education Standards, the NRC (1996) recommends that teacher practices in the classroom reflect current cognitive research as to how learning occurs. The second lens, teaching practices, is reflected in inquiry-based learning with support by neuropsychological research (Bransford, Brown, & Cocking, 1999). There are two categories of practice that are needed for an environment for learning through inquiry to thrive. These are identified in the NSES by the NRC (1996) as practices to use less often and practices to use more often. The analysis of this research indicates there is a relationship between the IFI and an increase or decrease of these practices.

The teaching of science is influenced by a perception that science is a subject that should be learned (NRC, 1996). The structure for the intervention, the IFI, incorporated the philosophy behind the inquiry as well as those strategies and methodologies indigenous to teaching science through inquiry. With this stated, the IFI can be an impetus for effecting change in teaching practice in elementary classrooms. The analysis indicates there is a relationship in lessening or increasing the use of those practices recommended by the National Research Council (2000) and the American Association of the Advancement of Science (1993).

Certain instructional practices should be used less frequently in the K-5 classroom (AAAS, 1993; NSRC, 1997). The data indicate a relationship exists between the IFI and a decrease in these practices. The data revealed the IFI participants do not treat all students the same. Student learning moves away from acquisition of facts and right/wrong tests. The classroom and lesson management is moving away from the teacher as the center of the classroom through lecture and control of all responsibility and
authority. There is a decline among teachers working in isolation to develop lessons. However, the one practice that continued to be used, in fact increased, is the use of competitive behavior among students as an instructional strategy.

Each of the practices the respondents indicated movement away from using in their classrooms has a counterpart mirrored as those practices that should be used more frequently. The recommendation by the NRC is to have teachers integrate these practices into their overarching pedagogical practices. The analysis states there is a relationship between the completion of the IFI and these instructional practices as evidenced in the movement away from the less emphasized behaviors and a movement toward using the more emphasized behaviors.

When the recommended behaviors are disaggregated, there is a change in the role of the student which indicates the student learning is actively constructed through individual and social processes (Brooks & Brooks, 1999; Bybee, 1982; NRC, 1996; Vygotsky, 1978). This is reflected in an increase by the teacher in responding to individual interests, experiences, strengths, and needs as concepts are developed, lessons are designed and/or instruction is delivered. This research shows a relationship between the use of inquiry and a process for developing student understanding and a subsequent demonstration of student knowledge, ideas, processes, and dispositions. This research shows the classroom is becoming a learning community reflecting shared responsibility for learning and the management of the classroom. Furthermore, the data indicates the educational community is stretching outside the classroom as the classroom teacher moves from developing lessons in isolation toward encompassing other teachers in the implementation of curriculum.
**Lens Three: Philosophy of Inquiry**

The third lens for observing change is philosophy in action because it is reflective of a change in beliefs about how students learn (Costa & Garmston, 1994). When people believe in an idea their behavior mirrors that belief (Hurd, 1993; Sousa, 2001). If the IFI impacts a change in beliefs, or philosophy, it follows there is a change in pedagogical practice. This is of particular importance because the teacher needs to believe in teaching science through inquiry before there will be a change in the related pedagogical practices (NRC, 1996, 2000) that incorporate and support inquiry methods and practices.

There are five observable behaviors that indicate a teaching philosophy in action and reflect inquiry articulated in a classroom. Each is observable in student practices for learning science. In each category over 50% of the 123 respondents stated they use these behaviors frequently since completing the IFI. The five behaviors that are evidence of belief in practice center upon students:

- engaging in meaningfully relevant scientific questions;
- using evidence in develop and explaining scientific questions;
- formulating questions derived from the evidence;
- evaluating their thinking against current science knowledge interplayed with their findings; and
- communicating and justifying their explanations.

These behaviors are a departure from the traditional methods of instruction inherent in science curricula that use a textbook as the primary conduit for information (Bybee, 1993; Exploratorium Institute for Inquiry, 1999; Presseisen, 1985).
The NRC (2000) states when the aforementioned essential behaviors are incorporated into classroom inquiry, the amount of learner self-initiative becomes more evident. In addition, there is a proportional decrease in the behavior of the teacher. The teacher begins the role for facilitating dialogue between students and teacher. Also, the role of the materials is to be the vehicle for translating the concepts for understanding and learning. Traditionally, materials were the focus. A change in belief is a shift toward believing the materials are the means to concept attainment and scientific dispositions. Subsequently, this change in beliefs is manifested through the use of curriculum and instructional practices that are indicative of a pedagogical philosophy that enhances the teaching for learning cycle for optimized learning for all students.

**Further Research**

In advancing these changes, professional development for teachers has at its core the mission of changing teacher practices. Furthermore, for professional development to be effective it must be ongoing, in-depth, and relevant (Hall & Hord, 2001; Loucks-Horsley, Hewson, Love, & Stiles, 1998). The relevance of research questions 4, 5, and 6 contribute to this argument. These three relate:

- to the number of years the respondents had taught relevant to the date of completion of the question;
- to the frequency of use of a resource teacher with regard to translation of inquiry into classroom practice through coaching, visiting, and/or collegial assistance; and
- to relevance of time and implementation of practice.
Even though for each of these there was no statistical significance, the previous data reveal behaviors that are significant in addressing the systemic change imperative to science reform (Bybee, 1993).

Although the data reveal no statistical relationship between how long a teacher has been teaching and the implementation of inquiry into practice, a comparison of years teaching experience, the frequent practice of having students do what scientists do (Doris, 1991) (a philosophy in action as stated previously), or the implementation of instructional strategies inherent to inquiry, indicates that the intervention is effective in bringing about change in practice. Of the 123 who responded to this question, the selected responses clustered around 3 – occasionally and 4 – frequently, when asked about the integration of the five indicators of inquiry in action (NRC, 2000) as instructional strategy. This clustering is not related to the number of years a teacher has been teaching. The implication from this research is that change can occur when a professional development experience models the philosophy and pedagogy, concurrently with the content, such as the IFI, whether a teacher is a novice or expert (Danielson & McGreal, 2000).

Additionally, a significant message, garnered from the data, is systemic change can occur irrespective of the scaffolding in place in a given educational system, such as mentors or coaches. It appears there is support for professional development that is ongoing and in-depth (The Glenn Commission Report, 2000; Loucks-Horsley, Hewson, Love, & Stiles, 1998). This researcher wonders what the impact upon the teaching for learning cycle could be if the scaffolding were to use a model for teacher enhancement such as Costa and Garmston (1994) and/or Danielson and McGreal (2000).
When the relationship between implementation of inquiry into practice is analyzed against the use of a coach/mentor (i.e., ASSET resource teacher), no statistical relationship emerges. For those who completed the questionnaire, their responses to the frequency of use of a resource teacher, had as their highest score, for all three situations, a 3 – occasional use. Occasional use is quantified in the questionnaire as two visits. The significance of this information further supports the role professional development can have upon implementing change. Professional development as recommended in The Glenn Commission Report and/or by the National Research Council states it must be ongoing and in-depth. If it is, the data from this research support the recommendations of these eminent groups.

The role of resource teachers is not to be diminished. Resource teachers are the facilitators of the IFI. It is their expertise that delivers the concepts that are inquiry-based. This researcher cannot but wonder what the impact would be if a mentoring/coaching model such as Danielson and McGreal (2000) or Costa and Garmston (1994) were instituted into a prescribed routine of professional development, such as in the IFI.

The last question was analyzed to determine if time has an impact on the implementation and use of those elements of inquiry. This research had at least one response from each group of the eleven IFIs. There was no statistically significant relationship between when a participant finished the IFI and the implementation of the use of inquiry. The participants translated the elements of inquiry into their pedagogical practices. Whether teachers were from the first IFI or from the last, there was self-reported use of the essential elements of inquiry in their teaching. The responses for all
eleven groups indicated a 3 – occasionally to 4 – frequently in using the five elements. The data are consistent in the responses.

In research there is an explanation for this. This parallels the research by Loucks-Horsley and her colleagues (1998, 2003). The model states professional development is fluid in design. The intervention can be aligned with the Loucks-Horsley model (2003, p. 4). The model has four key components of context, critical issues, knowledge and beliefs, and strategies. The components combine to generate a plan of action. The components can be described against the context of the intervention as:

- context of the experience relating to best practices;
- critical issues indigenous to the experience;
- knowledge and beliefs for presentation and implementation; and
- strategies for successful translation.

The model suggests the use of the four in devising an action plan. For this intervention, the plan of action becomes the implementation of the philosophy, methods, and practices of inquiry. It is the plan of action through which the rate of return of the translation to practice increases.

In addition, the Optimized Learning Opportunity model (OLO) showcased in Chapter Two warrants discussion relevant to the data analysis of this research. The OLO sets inquiry as the driver of change in curriculum, instruction, and philosophy. As inquiry generates the systemic impact to curriculum, instruction, and philosophy, it follows that there is a change in classroom environments which increase the likelihood for learning to be sustained over time.
The purpose for changing the teaching practices of K-5 teachers rests in student learning (Brooks & Brooks, 1999; Jensen, 1998; Stigler & Hiebert, 1999). The OLO model is a design for learning. With this research as support, the opportunity for all American children to be life-long learners, problem solvers, and collaborative learners has the opportunity for enhancement.

In summary, this research indicates there is a relationship between the IFI in impacting the use of inquiry-based hands-on science curriculum and the related strategies. The research herein depicts a relationship between the IFI, the intervention, and pedagogical practices attentive to the strategies for teaching science through inquiry. This research indicates a relationship between the intervention and a change in a belief system about what are the better methods for teaching science to children.

The three elements of curriculum, instruction, and philosophy are essential to address to effect change (Fullan, 2001). It follows that when these three elements generate energy for change, there is an impact in changing a system, such as an elementary classroom. When there is research based support for the direction and intensity of the system change, such as an elementary classroom, conditions can be created which structure and nurture an environment that impacts student understanding and learning (Dewey, 1938; NSRC, 1997; Resnick, 1987; Rousseau, 1969; Sousa, 2001).

**Recommendations for Further Research**

From the analysis and discussion, certain gaps appear to this researcher. To address them, further research is recommended. The intent of the following recommendations is to strengthen and clarify findings or to enhance elements of the
intervention. To assist in the goal of systemic change in the teaching of science in K-5 classrooms, these recommendations are offered:

1. The analysis indicated a minimal, a mean difference of +0.1, increase in use of modules. Could the appropriateness or depth of use of the module have increased as a result of participation in the IFI? This researcher recommends an exploration of the relationship between the IFI and the change in usage of the science modules. The intent is to explore the instructional strategies that are directly attributable to the IFI graduates from this intervention when incorporating the use of modules in their curriculum.

2. The analysis of the data indicates teachers have begun to move away from the prescribed practices as set forth in the teacher manuals, even those related to the modules, specifically embedded instructions, worksheets, short answer tests, and textbooks. The next question asks for investigation into a statistical relationship between the IFI and teacher self-efficacy. Did this movement occur because of the IFI? How significant is teacher self-efficacy to this departure from prescribed lessons?

3. A philosophy in practice is evidenced in the NRC (2000) five essential elements which exhibits student application of inquiry in their science courses to demonstrate understanding and learning. To further support the reported frequency of use, it is recommended interviews with students be conducted. The interview would be a vignette and the student would describe the inquiry process intrinsic to the science learning.
4. The analysis did not indicate a statistical relationship between the intervention by a resource teacher and a change in teaching practice. Further research that identifies active coaching/support/intervention by a resource teacher could reveal a statistically significant relationship.

5. In the NSF grant proposal guidelines there is specific reference for the use of teachers to teach teachers about science through inquiry. This researcher wonders what the impact for learning could be if the RTs were classroom teachers of the same practice the IFI purports. Could RT who taught using inquiry in their classrooms have a significant impact on advancing student learning through inquiry?

6. The fifth day of the IFI requires the participants to share how they have begun the translation of their inquiry experience into their pedagogical practice. This requirement is another modeling by the facilitators of the process of inquiry. It is the design of a question (i.e., a practice in their classroom) and a reporting out of their findings in relation to what they know. The questionnaire did not ask the respondents to indicate their perspective on the impact this might have had on their use of inquiry. Further research would be to explore a relationship between the fifth day assignment and the translation to practice in using inquiry as preferred pedagogy.

7. A next step is to determine student learning. Changing pedagogical practice was the beginning. This research demonstrated there is a relationship between long-term in-depth professional development and change in practice. The
next step would be to determine the impact this change in teaching practice has upon student learning.

8. There is no indication that time, whether as completion of the IFI or years teaching, affects the use of inquiry as a pedagogical practice. In the questionnaire, the participants were not asked to rate the different components of the IFI or to state if they attended all five days of the IFI. Further research would be to explore which of the components of the IFI have an effect on the translation of inquiry into practice in classrooms.

9. A limitation of this research is the questionnaire. It was self-reported. Further research would be to visit individual classrooms to observe the five essential elements of inquiry in practice in those classrooms.

10. Other research states that translation to practice requires time for reflection between the intervention and implementation (Guskey, 2000). Guskey (2000) goes on to state there is a need for support within the educational community. These two factors are important for translation to practice, specifically the later. Trying new behaviors can be intimidating. Support is needed to help through the trial and error process. The data from this research indicates there is a translation of the intervention to practice without either time or support playing a significant role. Further research is suggested to determine if the structure of the intervention of four meetings every other week is addressing the time factor. Also, the requirement of the intervention to apply the experience to the classroom and report their finding is the personal support of
the educational community. Or is this intervention shedding a new perspective.

**Conclusions**

In conclusion, there is a statistical relationship between the IFI and change in how teachers teach science. For change to occur, it must be systemic (Fullan, 2001; NRC, 1996). The relationship between the IFI and change in pedagogical practice suggests it as an avenue for systemic change in teaching science through inquiry. The pedagogy and philosophy of inquiry assists in meeting the national goal for life-long learners, problem solvers, and collaborative learners (The Glenn Commission Report, 2000; Layman, 1996).

One of the key elements of the science initiatives supported by the National Science Foundation was the concept of teachers teaching teachers. The research presented here adds a dimension to this approach. The participants reported only an occasional visit by a resource teacher. If resource teachers were to be proactive in the interplay between the IFI and the translation to practice of inquiry, this scaffold offers an opportunity to strengthen the implementation of inquiry as a pedagogical practice.

**Summary**

The research suggests a relationship between changes in teacher practices and the intervention of the ASSET Institute for Inquiry. Using Fullan’s three essential elements of curriculum, instruction, and philosophy as a lens to examine change in teaching practice with regard to science instruction, the analysis held that the intervention affected such changes as follows:
• There is a significant statistical relationship between the use of inquiry-based science curriculum and the IFI.

• There is a significant statistical relationship between instructional strategies and the IFI.

• There is an increase in the frequency of practice that is demonstrative of the philosophy of a teacher, or belief in action.

• There was no statistical relationship between years of experience teaching, use of a mentor/coach (e.g., ASSET resource teacher), and that the time interval between attendance of the IFI and translation to practice. It appears to happen because of professional development that is in-depth and on-going.
### Glossary of Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAAS</td>
<td>American Association for the Advancement of Science: The largest general scientific organization in the country and the largest federation of scientific societies in the world responsible for the publications <em>Science for All Americans</em>, on scientific literacy and <em>Benchmarks for Science Literacy</em>, a curriculum design tool defining expectations for science knowledge.</td>
</tr>
<tr>
<td>ASSET</td>
<td>Allegheny Schools Science and Technology: Is an independent non-profit organization formed in 1992 through the leadership and fiscal support of Bayer Corporation. Its vision is to help educators foster outstanding student achievement in science and technology.</td>
</tr>
<tr>
<td>CBAM</td>
<td>Concerns-Based Adoption Model: A model about change that is rooted in a number of verified assumptions about how schools might go about improving successfully. It was developed at the Development Center for Teacher Education at the University of Texas at Austin.</td>
</tr>
<tr>
<td>IFI</td>
<td>Institute for Inquiry: The flagship of the ASSET Inc. professional development opportunities which is modeled and adapted from the Inquiry Institute at the Exploratorium in San Francisco, California. The adaptation is in the using the resource teacher (RT) as a transformational leader.</td>
</tr>
<tr>
<td>LSC</td>
<td>Local Systemic Change: Now termed Local Systemic Initiatives.</td>
</tr>
<tr>
<td>NDEA</td>
<td>National Defense Education Act: Passed 1958 and directed significant federal funding to revision of curriculum in the areas of mathematics, science and modern languages in line with the latest theories and methods.</td>
</tr>
</tbody>
</table>
NSF  National Science Foundation, Directorate for Education and Human Resources: The Directorate for Education and Human Resources of the National Science Foundation, an independent federal agency, is a major force in science education reform. Within is the Office of Systemic Reform which manages three large-scale reform projects: the Rural Systemic Initiatives, Statewide systemic Initiatives, and Urban Systemic Initiatives. These three reform projects support efforts to make systemic improvements in science, mathematics, and technology education in rural regions, urban regions, and statewide.

NRC  National Research Council: Is the operating arm of three honorary academies: the National Academy of Sciences, the National Academy of Engineering, and Institute of Medicine. Its primary function is advising the federal government on science and technology policy.

NSRC  National Science Resources Center: Organization sponsored jointly by the National Academy of Sciences and the Smithsonian Institution to contribute to the improvement of science education in the nation’s schools.

NSTA  National Science Teachers Association: Organization committed to improving science education at all levels (pre-K through college).

RT  Resource Teacher: At ASSET Inc. teachers provide high-quality professional development to classroom teachers through institutes, courses and mentoring. They also conduct teacher-driven study groups for
educators throughout Allegheny County of Pennsylvania and are recognized as the region’s specialists in inquiry-based education.
References


Appendix A

Permission from Horizon Research, Inc.
October 29, 2003

Joseph A. Sciulli
913 Beech Avenue
Pittsburgh, PA 15233-1752

Dear Mr. Sciulli:

You have our permission to use the survey format and items that relate to teacher assessment in your dissertation as long as you acknowledge Horizon Research, Inc. and the National Science Foundation.

Sincerely,

Iris R. Weiss
President

IRW/sbh
Appendix B

Permission from the National Science Resources Center
November 4, 2003

Mr. Joe Sciulli
913 Beech Avenue
Pittsburgh, PA 15233-1752

Dear Joe:

On behalf of the National Science Resources Center (NSRC) I would like to acknowledge your request to use the *Theory of Action* concept and image, which is a copyright of the NSRC.

Please consider this letter as permission for said concept and image to be used in your dissertation.

Thank you for your inquiry and good luck.

SINCERELY,

Wendy Binder
SENIOR PROGRAM ASSOCIATE
NATIONAL SCIENCE RESOURCES CENTER
THE LASER CENTER
Appendix C

National Science Education Standards: Less – More Emphasis
Appendix C

The *National Science Education Standards* envision change throughout the education system. The teaching standards encompass the following changes in emphasis:

<table>
<thead>
<tr>
<th>Less emphasis on:</th>
<th>More Emphasis on:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treating all students alike and responding to the group as a whole.</td>
<td>Understanding and responding to individual student’s interests, strengths, experiences and needs.</td>
</tr>
<tr>
<td>Rigidly following curriculum.</td>
<td>Selecting and adapting curriculum.</td>
</tr>
<tr>
<td>Focusing on student acquisition of information.</td>
<td>Focusing on student understanding and use of scientific knowledge, ideas and inquiry processes.</td>
</tr>
<tr>
<td>Presenting scientific knowledge through lecture, text and demonstration.</td>
<td>Guiding students in active and extended scientific inquiry.</td>
</tr>
<tr>
<td>Testing students for factual information at the end of each chapter.</td>
<td>Continuously assessing student understanding.</td>
</tr>
<tr>
<td>Maintaining responsibility and authority.</td>
<td>Sharing responsibility for learning with students.</td>
</tr>
<tr>
<td>Supporting competition.</td>
<td>Supporting a classroom community with cooperation, shared responsibility and respect.</td>
</tr>
<tr>
<td>Working alone.</td>
<td>Working with other teachers to enhance the science program.</td>
</tr>
</tbody>
</table>

From the National Research Council (1996) *National Science Education Standards* (p.52).
Appendix D

Recommendations by National Commission on Excellence in Education
## Recommendations by National Commission on Excellence in Education

### Recommendation A: Content

We [National Commission on Excellence in Education] recommend that State and local high school graduation requirements be strengthened and that, at a minimum, all students seeking a diploma be required to lay the foundations in the Five New Basics by taking the following curriculum during their 4 years of high school: (a) 4 years of English; (b) 3 years of mathematics; (c) 3 years of science; (d) 3 years of social studies; and (e) one-half year of computer science. For the college-bound, 2 years of foreign language in high school are strongly recommended in addition to those taken earlier.

### Recommendation B: Standards and Expectations

We recommend that schools, colleges, and universities adopt more rigorous and measurable standards, and higher expectations, for academic performance and student conduct, and that 4-year colleges and universities raise their requirements for admission. This will help students do their best educationally with challenging materials in an environment that supports learning and authentic accomplishments.

### Recommendation C: Time

We recommend that significantly more time be devoted to learning the New Basics. This will require more effective use of the existing school day, a longer school day, or a lengthened school year.

### Recommendation D: Teaching

This recommendation consists of seven parts. Each is intended to improve the preparation of teachers or to make teaching a more rewarding and respected profession. Each of the seven stands on its own and should not be considered solely as an implementing recommendation.

### Recommendation E: Leadership and Fiscal Support

We recommend that citizens across the Nation hold educators and elected officials responsible for providing the leadership necessary to achieve these reforms, and that citizens provide the fiscal support and stability required to bring about the reforms we propose.

From the National Commission on Excellence in Education (1983) *A Nation at Risk* (pp.24-33).
Appendix E

Alert letter pertaining to questionnaire
Dear Colleague:

A few days from now you will receive, in the mail, a request to complete a brief questionnaire (about twenty minutes to complete) for my research project. This research project is part of the requirements for the dissertation I am writing as a doctoral candidate at Duquesne University. It is titled, *Teaching Science through Inquiry in K-5 Classrooms: Analysis of Change in Practice.* It concerns the experiences and opinions of graduates of an ASSET Institute for Inquiry.

I am writing in advance because I have found many people like to know ahead of time that they will be contacted. The importance of the study is in its focus on the impact professional development can have when teachers translate inquiry into practice in their classrooms. Within the forthcoming questionnaire, I will address the issues of confidentiality and the significance of this research.

Thank you for your time and consideration. It is only with the generous help of people like you that my research can be successful.

Sincerely yours,

Joseph A. Sciulli
Appendix F

IRB Consent to Participate Letter
CONSENT TO PARTICIPATE IN A RESEARCH STUDY

INVESTIGATOR:       Joseph A. Sciulli
                     913 Beech Avenue
                     Pittsburgh, PA 15233-1752
                     412.322.4313
                     JoeSciulli@worldnet.att.net

TITLE OF RESEARCH PROJECT: Teaching Science through Inquiry in K-5 Classrooms:
                          Analysis of Change in Practice

ADVISOR:             Barb Manner, Ph.D.
                     Associate Professor
                     Duquesne University
                     School of Education
                     110C Canevin Hall
                     Pittsburgh, Pennsylvania 15282
                     Phone: 412.396.6106 and 412.396.5482
                     Email: manner@duq.edu

SOURCE OF SUPPORT:   This study is being performed as partial fulfillment of the
                     requirements for the doctoral degree in the School of
                     Education at Duquesne University.

PURPOSE:             You are being asked to participate in a research project
                     that seeks to investigate the relationship between the
                     Institute for Inquiry and a change in the teaching practices.
                     You will be mailed a questionnaire that takes
                     approximately twenty minutes to complete. You are
                     asked to share your reflections prior to and since your
                     participation in the Institute for Inquiry. There is a
                     postage paid return envelope for the return of the
                     questionnaire. This completion of the questionnaire is the
                     only request that will be made of you.
COMPENSATION: You will not receive any compensation for your participation in this study. However, participation in this project will require no monetary cost to you. An envelope is provided for return of your questionnaire to the investigator.

RISKS AND BENEFITS: There is no risk to you. The information garnered will be used to support on-going professional development. Also, if teaching science through inquiry is to be supported, then translation of the philosophy and theory of inquiry to practice in elementary classrooms requires analysis. You responses in the questionnaire will assist in this analysis.

CONFIDENTIALITY: Your name will never appear on any survey or research instruments. No identity will be made in the data analysis. All written materials will be stored in a locked file in the researcher’s home. Your responses will only appear in statistical data summaries. All materials will be destroyed at the completion of the research.

RIGHT TO WITHDRAW: You are under no obligation to participate in this study. You are free to withdraw your consent to participate by just returning your unused questionnaire.

SUMMARY OF RESULTS: A summary of the results of this research will be supplied to you, at no cost, upon request.

VOLUNTARY CONSENT: This questionnaire is voluntary. After reading the above statements and you are clear about what is being asked of you, you can indicate voluntary participation by completing the questionnaire and returning it to this researcher. Also, you are free to withdraw your consent at any time, for any reason.

If you have any further questions about participation in this study, please call Dr. Paul Richer, Chair of the Duquesne University Institutional Review Board at 412.396.6326

Thank you for taking the time from your busy schedule to help me with my research. Your collegial support is greatly appreciated.

Sincerely yours,

Joseph A. Sciulli
Appendix G

Follow-up postcard
Appendix G

December 1, 2003

Last week a questionnaire seeking your opinions about the Institute for Inquiry was mailed to you.

If you have already completed and returned the questionnaire to me, please accept my sincere thanks. If not, please do so today. I am especially grateful for your help because it is only by asking teachers like you to share your experience and opinions that an understanding of the impact of professional development can have upon the use of inquiry in classrooms.

If you did not receive a questionnaire, or it was misplaced, please call me at 412-322-4313 or email at JoeSciulli@worldnet.att.net and I will get another one in the mail to you today.

Joseph A. Sciulli
Duquesne University Doctoral Candidate

December 1, 2003

Last week a questionnaire seeking your opinions about the Institute for Inquiry was mailed to you.

If you have already completed and returned the questionnaire to me, please accept my sincere thanks. If not, please do so today. I am especially grateful for your help because it is only by asking teachers like you to share your experience and opinions that an understanding of the impact of professional development can have upon the use of inquiry in classrooms.

If you did not receive a questionnaire, or it was misplaced, please call me at 412-322-4313 or email at JoeSciulli@worldnet.att.net and I will get another one in the mail to you today.

Joseph A. Sciulli
Duquesne University Doctoral Candidate
Appendix H

Questionnaire
Teaching Science through Inquiry in K-5 Classrooms: 
Analysis of Change in Practice

Questionnaire

You have been selected to participate in a research study being performed as partial fulfillment of the requirements for a doctoral degree in the School of Education at Duquesne University.

It will take approximately twenty minutes to complete this questionnaire. You can use a pen or pencil to answer the questions.

Your cooperation is completely voluntary. Data collection procedures have been developed to ensure quality and to protect teacher confidentiality. Your responses will be kept strictly confidential; they will be combined with the responses of other teachers and used only for research. The tracking # is being used to follow up with those teachers who have not responded; no information identifying individual teachers will be reported under any circumstances. After completion of the questionnaire, please mail it in the envelope provided. The Institute for Inquiry Session information is to answer question number 4.

Thank you for taking time from your busy day to help with this research.
### Teaching Science through Inquiry in K-5 Classrooms

#### Questionnaire – 2003

**Instructions:** Please complete this questionnaire. Be sure to erase completely any stray marks.

1. Please take a moment and **reflect** on your teaching **PRIOR** to attending the ASSET Institute for Inquiry. During a typical week of teaching science, please rate each of the following items in terms of the frequency of use by you when teaching science. (Circle one number.)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>Never</th>
<th>Rarely</th>
<th>Occasionally</th>
<th>Frequently</th>
<th>Always</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>Worked with other teachers to enhance the science program</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b.</td>
<td>Treated all students alike and responded to the group as a whole</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c.</td>
<td>Guided students in active and extended scientific inquiry</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d.</td>
<td>Shared responsibility for learning with my students</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>e.</td>
<td>Tested students for factual information at the end of each chapter</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>f.</td>
<td>Continuously assessed student understanding</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>g.</td>
<td>Supported a classroom community with cooperation, shared responsibility, and respect</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>h.</td>
<td>Understood and responded to individual student interests, strengths, experiences and needs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>i.</td>
<td>Followed the curriculum as written</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>j.</td>
<td>Supported competitive learning and behavior</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>k.</td>
<td>Maintained responsibility and authority</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>l.</td>
<td>Focused on student acquisition of information</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>m.</td>
<td>Focused on student understanding and use of scientific knowledge, ideas, and inquiry processes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>n.</td>
<td>Worked alone on lesson development and planning</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>o.</td>
<td>Presented scientific knowledge through lecture, text, and demonstration</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>p.</td>
<td>Selected and adapted the curriculum</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
2. Please take a moment and reflect on your teaching PRIOR to attending the ASSET Institute for Inquiry. During a typical week of teaching science, please rate each of the following items in terms of the frequency of use by you when teaching science. (Circle one number.)

<p>| | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Provided concrete experience before abstract concepts</td>
<td>Never</td>
<td>Rarely</td>
<td>Occasionally</td>
<td>Frequently</td>
<td>Always</td>
</tr>
<tr>
<td>b. Developed students’ conceptual understanding of science</td>
<td>Never</td>
<td>Rarely</td>
<td>Occasionally</td>
<td>Frequently</td>
<td>Always</td>
</tr>
<tr>
<td>c. Took students’ prior understanding into account when planning curriculum and instruction</td>
<td>Never</td>
<td>Rarely</td>
<td>Occasionally</td>
<td>Frequently</td>
<td>Always</td>
</tr>
<tr>
<td>d. Made connections between science and other disciplines</td>
<td>Never</td>
<td>Rarely</td>
<td>Occasionally</td>
<td>Frequently</td>
<td>Always</td>
</tr>
<tr>
<td>e. Had students participate in appropriate hands-on activities</td>
<td>Never</td>
<td>Rarely</td>
<td>Occasionally</td>
<td>Frequently</td>
<td>Always</td>
</tr>
<tr>
<td>f. Engaged students in inquiry-oriented activities</td>
<td>Never</td>
<td>Rarely</td>
<td>Occasionally</td>
<td>Frequently</td>
<td>Always</td>
</tr>
<tr>
<td>g. Engaged students in applications of science in a variety of contexts</td>
<td>Never</td>
<td>Rarely</td>
<td>Occasionally</td>
<td>Frequently</td>
<td>Always</td>
</tr>
<tr>
<td>h. Had students work in cooperative and/or collaborative learning groups</td>
<td>Never</td>
<td>Rarely</td>
<td>Occasionally</td>
<td>Frequently</td>
<td>Always</td>
</tr>
<tr>
<td>i. Used performance-based assessment</td>
<td>Never</td>
<td>Rarely</td>
<td>Occasionally</td>
<td>Frequently</td>
<td>Always</td>
</tr>
<tr>
<td>j. Used informal questioning to assess student understanding</td>
<td>Never</td>
<td>Rarely</td>
<td>Occasionally</td>
<td>Frequently</td>
<td>Always</td>
</tr>
</tbody>
</table>

3. How many college science courses have you completed? (Check one square.)

- None
- 1 semester
- 2 semesters
- 3 semesters
- 4 semesters
- 5 semesters

4. When did you attend the ASSET Institute for Inquiry? If you have forgotten the semester, the cover letter accompanying this questionnaire indicates when you attended the Institute for Inquiry at ASSET. It is located in the upper right hand corner of the letter. (Check one square.)

- Fall 2000
- Winter 2001
- Spring 2001
- Summer 2001
- Fall 2001
- Winter 2002
- Spring 2002
- Summer 2002
- Fall 2002
- Winter 2003
- Spring 2003

5. How many science modules, or science kits, sent to you from ASSET, do you receive each academic year? (Check one square.)

- 1
- 2
- 3
- 4
6. Please take a moment and **reflect** on your teaching **PRIOR** to attending the ASSET Institute for Inquiry. During a typical week of teaching science, please rate each of the following items in terms of the frequency of use by you when teaching science. (Circle one number.)

<table>
<thead>
<tr>
<th>Item</th>
<th>Never</th>
<th>Rarely</th>
<th>Occasionally</th>
<th>Frequently</th>
<th>Always</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Used the materials in the modules from ASSET as the basis of science lessons .....</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>b. Students worked in cooperative groups ........................................</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>c. Students read from a science textbook in class ................................</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>d. Students read other (non-textbook) science-related materials in class ..........</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>e. Students answered textbook/worksheet questions ................................</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>f. Students engaged in hands-on science activities ...................................</td>
<td>1</td>
<td>2</td>
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<td>4</td>
<td>5</td>
</tr>
<tr>
<td>g. Students followed specific instructions in an activity or investigation ..............</td>
<td>1</td>
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<td>5</td>
</tr>
<tr>
<td>h. Students designed or implemented their <em>own</em> investigations ...........................</td>
<td>1</td>
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<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>i. Students worked on models or simulations ............................................</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>j. Students worked on extended science investigations or projects (a week or more in duration) ..................................</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>k. Students participated in field work (e.g., worked in class garden, took field trip) ...</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>l. Students wrote reflections in a notebook or journal ...................................</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>m. Students used mathematics as a tool in problem-solving ...............................</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>n. Students used computers ..............................................................</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>o. Students worked with portfolios ......................................................</td>
<td>1</td>
<td>2</td>
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<td>p. Students took short-answer tests (e.g., multiple-choice, true/false, fill-in-the-blank) ..................................</td>
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<td>q. Students took tests requiring open-ended responses (e.g., descriptions, explanations) ..................................</td>
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<td>r. Students engaged in performance tasks for assessment purposes ..........................</td>
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<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>
7. How many years have you been using the science modules, or science kits?

□ 1st year □ 2nd year □ 3rd year □ 4th year □ 5th or more years

8. How many years have you taught including this school year? (Check one square.)

□ 0-2 □ 3-5 □ 6-10 □ 11-15 □ 16-20 □ 21-25 □ 26 or more

9. Please take a moment and reflect on the ASSET Resource Teacher who was assigned to you. Please rate each of the following in terms of the frequency of use by you in utilizing the Resource Teacher as you implemented the concepts and methods from the Institute for Inquiry.

- Never = No visits
- Rarely = One visit
- Occasionally = Two visits
- Frequently = Three or four visits
- Always = Five or more visits

a. Was “coached” on my teaching by the Resource Teacher

<table>
<thead>
<tr>
<th>Never</th>
<th>Rarely</th>
<th>Occasionally</th>
<th>Frequently</th>
<th>Always</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

b. Was visited by the Resource Teacher

<table>
<thead>
<tr>
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<th>Always</th>
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<td>5</td>
</tr>
</tbody>
</table>

c. Received assistance from the Resource Teacher

<table>
<thead>
<tr>
<th>Never</th>
<th>Rarely</th>
<th>Occasionally</th>
<th>Frequently</th>
<th>Always</th>
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</thead>
<tbody>
<tr>
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<td>2</td>
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<td>5</td>
</tr>
</tbody>
</table>

10. How would you rate the overall quality of the Institute for Inquiry? (Check one square.)

□ Poor □ Fair □ Good □ Very good □ Excellent

11. How much of an impact has the Institute for Inquiry had on your teaching of science? (Check one square.)

□ None □ Some □ Neutral □ A lot □ A great deal

12. What grade level do you teach? (Check one square.)

□ K □ 1 □ 2 □ 3 □ 4 □ 5

13. Do you teach in a self-contained classroom (i.e., you are responsible for teaching several subjects to one class)? (Check one square.)

□ Yes □ No

14. How many lessons per week do you typically teach science to a class? (Check one square.)

□ 0 □ 1 □ 2 □ 3 □ 4 □ 5

15. Approximately how many minutes is a typical science lesson? (Check one square.)

□ 10 or fewer □ 11-20 □ 21-30 □ 31-40 □ 41-50 □ 51-60 □ 61-70 □ 71-80 □ 81 or more
16. To what extent has your participation in the Institute for Inquiry increased your: (Circle one number.)

<table>
<thead>
<tr>
<th></th>
<th>Science content knowledge</th>
<th>Not at all</th>
<th>Some</th>
<th>Neutral</th>
<th>A lot</th>
<th>To a great extent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Understanding of how children think about and learn science</th>
<th>Not at all</th>
<th>Some</th>
<th>Neutral</th>
<th>A lot</th>
<th>To a great extent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td>5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Ability to implement high-quality science instructional materials</th>
<th>Not at all</th>
<th>Some</th>
<th>Neutral</th>
<th>A lot</th>
<th>To a great extent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tr>
</tbody>
</table>

17. Please take a moment and reflect on your teaching SINCE attending the ASSET Institute for Inquiry. During a typical week of teaching science, please rate each of the following items in terms of the frequency of use by you when teaching science. (Circle one number.)

<table>
<thead>
<tr>
<th></th>
<th>Provide concrete experience before abstract concepts...............</th>
<th>Never</th>
<th>Rarely</th>
<th>Occasionally</th>
<th>Frequently</th>
<th>Always</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td>5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Develop students’ conceptual understanding of science...............</th>
<th>Never</th>
<th>Rarely</th>
<th>Occasionally</th>
<th>Frequently</th>
<th>Always</th>
</tr>
</thead>
<tbody>
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</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Take students’ prior understanding into account when planning curriculum and instruction..................</th>
<th>Never</th>
<th>Rarely</th>
<th>Occasionally</th>
<th>Frequently</th>
<th>Always</th>
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<table>
<thead>
<tr>
<th></th>
<th>Make connections between science and other disciplines...............</th>
<th>Never</th>
<th>Rarely</th>
<th>Occasionally</th>
<th>Frequently</th>
<th>Always</th>
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<table>
<thead>
<tr>
<th></th>
<th>Have students participate in appropriate hands-on activities................</th>
<th>Never</th>
<th>Rarely</th>
<th>Occasionally</th>
<th>Frequently</th>
<th>Always</th>
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<table>
<thead>
<tr>
<th></th>
<th>Engage students in inquiry-oriented activities........................</th>
<th>Never</th>
<th>Rarely</th>
<th>Occasionally</th>
<th>Frequently</th>
<th>Always</th>
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<table>
<thead>
<tr>
<th></th>
<th>Engage students in applications of science in a variety of contexts..............</th>
<th>Never</th>
<th>Rarely</th>
<th>Occasionally</th>
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<th>Always</th>
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<table>
<thead>
<tr>
<th></th>
<th>Have students work in cooperative and/or collaborative learning groups................</th>
<th>Never</th>
<th>Rarely</th>
<th>Occasionally</th>
<th>Frequently</th>
<th>Always</th>
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<thead>
<tr>
<th></th>
<th>Use performance-based assessment................................</th>
<th>Never</th>
<th>Rarely</th>
<th>Occasionally</th>
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</table>

<table>
<thead>
<tr>
<th></th>
<th>Use informal questioning to assess student understanding...................</th>
<th>Never</th>
<th>Rarely</th>
<th>Occasionally</th>
<th>Frequently</th>
<th>Always</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<tr>
<th></th>
<th></th>
<th>Never</th>
<th>Rarely</th>
<th>Occasionally</th>
<th>Frequently</th>
<th>Always</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Work with other teachers to enhance the science program</td>
<td></td>
<td>1</td>
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</tr>
<tr>
<td>b. Treat all students alike and responded to the group as a whole</td>
<td></td>
<td>1</td>
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<td>5</td>
</tr>
<tr>
<td>c. Guide students in active and extended scientific inquiry</td>
<td></td>
<td>1</td>
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<td>5</td>
</tr>
<tr>
<td>d. Share responsibility for learning with my students</td>
<td></td>
<td>1</td>
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<td>5</td>
</tr>
<tr>
<td>e. Test students for factual information at the end of each chapter</td>
<td></td>
<td>1</td>
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</tr>
<tr>
<td>f. Continuously assess student understanding</td>
<td></td>
<td>1</td>
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<td>5</td>
</tr>
<tr>
<td>g. Support a classroom community with cooperation, shared responsibility, and respect</td>
<td></td>
<td>1</td>
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<td>4</td>
<td>5</td>
</tr>
<tr>
<td>h. Understand and respond to individual student interests, strengths, experiences and needs</td>
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<td>5</td>
</tr>
<tr>
<td>i. Follow the curriculum as written</td>
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<td>1</td>
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<tr>
<td>j. Support competitive learning and behavior</td>
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<td>1</td>
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<td>5</td>
</tr>
<tr>
<td>k. Maintain responsibility and authority</td>
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<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>l. Focus on student acquisition of information</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>m. Focus on student understanding and use of scientific knowledge, ideas, and inquiry processes</td>
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<td>1</td>
<td>2</td>
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<td>4</td>
<td>5</td>
</tr>
<tr>
<td>n. Work alone on lesson development and planning</td>
<td></td>
<td>1</td>
<td>2</td>
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<td>4</td>
<td>5</td>
</tr>
<tr>
<td>o. Present scientific knowledge through lecture, text, and demonstration</td>
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<td>1</td>
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<td>5</td>
</tr>
<tr>
<td>p. Select and adapt the curriculum</td>
<td></td>
<td>1</td>
<td>2</td>
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During a typical week of teaching science, please rate each of the following items in terms of the frequency of use by you when teaching science. *(Circle one number.)*

<p>| | | | | |</p>
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<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>a.</strong> Use the materials in the modules from ASSET as the basis of science lessons</td>
<td>Never</td>
<td>Rarely</td>
<td>Occasionally</td>
<td>Frequently</td>
</tr>
<tr>
<td><strong>b.</strong> Have my students work in cooperative groups</td>
<td>Never</td>
<td>Rarely</td>
<td>Occasionally</td>
<td>Frequently</td>
</tr>
<tr>
<td><strong>c.</strong> Have my students read from a science textbook in class</td>
<td>Never</td>
<td>Rarely</td>
<td>Occasionally</td>
<td>Frequently</td>
</tr>
<tr>
<td><strong>d.</strong> Have my students read other (non-textbook) science-related materials in class</td>
<td>Never</td>
<td>Rarely</td>
<td>Occasionally</td>
<td>Frequently</td>
</tr>
<tr>
<td><strong>e.</strong> Have my students answer textbook/worksheet questions</td>
<td>Never</td>
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<td>Occasionally</td>
<td>Frequently</td>
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<tr>
<td><strong>f.</strong> Have my students engage in hands-on science activities</td>
<td>Never</td>
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<td>Occasionally</td>
<td>Frequently</td>
</tr>
<tr>
<td><strong>g.</strong> Have my students follow specific instructions in an activity or investigation</td>
<td>Never</td>
<td>Rarely</td>
<td>Occasionally</td>
<td>Frequently</td>
</tr>
<tr>
<td><strong>h.</strong> Have my students design or implement their own investigations</td>
<td>Never</td>
<td>Rarely</td>
<td>Occasionally</td>
<td>Frequently</td>
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<tr>
<td><strong>i.</strong> Have my students work on models or simulations</td>
<td>Never</td>
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<td>Occasionally</td>
<td>Frequently</td>
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<tr>
<td><strong>j.</strong> Have my students work on extended science investigations or projects (a week or more in duration)</td>
<td>Never</td>
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</tr>
<tr>
<td><strong>k.</strong> Students participated in field work (e.g., worked in class garden, took field trip)</td>
<td>Never</td>
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<td>Occasionally</td>
<td>Frequently</td>
</tr>
<tr>
<td><strong>l.</strong> Have my students write reflections in a notebook or journal</td>
<td>Never</td>
<td>Rarely</td>
<td>Occasionally</td>
<td>Frequently</td>
</tr>
<tr>
<td><strong>m.</strong> Have my students use mathematics as a tool in problem-solving</td>
<td>Never</td>
<td>Rarely</td>
<td>Occasionally</td>
<td>Frequently</td>
</tr>
<tr>
<td><strong>n.</strong> Have my students use computers</td>
<td>Never</td>
<td>Rarely</td>
<td>Occasionally</td>
<td>Frequently</td>
</tr>
<tr>
<td><strong>o.</strong> Have my students work with portfolios</td>
<td>Never</td>
<td>Rarely</td>
<td>Occasionally</td>
<td>Frequently</td>
</tr>
<tr>
<td><strong>p.</strong> Have my students take short-answer tests (e.g., multiple-choice, true/false, fill-in-the-blank)</td>
<td>Never</td>
<td>Rarely</td>
<td>Occasionally</td>
<td>Frequently</td>
</tr>
<tr>
<td><strong>q.</strong> Have my students take tests requiring open-ended responses (e.g., descriptions, explanations)</td>
<td>Never</td>
<td>Rarely</td>
<td>Occasionally</td>
<td>Frequently</td>
</tr>
<tr>
<td><strong>r.</strong> Have my students engaged in performance tasks for assessment purposes</td>
<td>Never</td>
<td>Rarely</td>
<td>Occasionally</td>
<td>Frequently</td>
</tr>
</tbody>
</table>
20. Please take a moment and **reflect** on your teaching **SINCE** attending the ASSET Institute for Inquiry. During a typical week of teaching science, please rate each of the following items in terms of the frequency of use by you when teaching science. (Circle one number.)

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<thead>
<tr>
<th></th>
<th></th>
<th>Never</th>
<th>Rarely</th>
<th>Occasionally</th>
<th>Frequently</th>
<th>Always</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>Students were engaged by meaningful and relevant scientifically oriented questions ...</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>b.</td>
<td>Students gave priority to evidence allowing them to develop and evaluate explanations that address their scientifically oriented questions ................................</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>c.</td>
<td>Students formulated an explanation based on the evidence from their investigation ...</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>d.</td>
<td>Students evaluated their explanations consistent with currently accepted scientific knowledge ..........................</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>e.</td>
<td>Students communicated and justified their explanations .................................................</td>
<td>1</td>
<td>2</td>
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</tr>
</tbody>
</table>

---

21. Are you a:  □ Male    □ Female

---

22. How long do your science units typically last? (Check one square.)

□ One week
□ Two weeks
□ Three weeks
□ Four weeks
□ Five weeks
□ Six weeks
□ Seven weeks
□ Eight weeks
□ Nine weeks
□ Ten weeks

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Thank you for taking time from your busy day to help with this research.
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In addition:
