VERBAL AND SOCIAL INTERACTION PATTERNS AMONG ELEMENTARY
STUDENTS DURING SELF-GUIDED “I WONDER PROJECTS”

DISSERTATION

Presented in Partial Fulfillment of the Requirements for
the Degree Doctor of Philosophy in the Graduate
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By

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ABSTRACT

National standards for science teaching stress the use of inquiry teaching methods. One example of inquiry teaching is the I Wonder Project, which has been used in the Madison, WI Metropolitan School District for over ten years. The purpose of the I Wonder Project is to promote scientific discourse among elementary students through the publication of their research in a journal, similar in some ways to the scientific discourse within a community of scientists. This research study utilizes the I Wonder Project method to encourage student communication and self-guided project work.

Approximately fifteen students ages 6-12 participated in a six-week self-guided inquiry project called I Wonder. Students worked as a cohort to learn science process skills and to build a scientific community. During this time, each student designed and carried out a self-guided inquiry project and wrote an article about their findings, which was presented on the last day of summer camp.

A mixed method approach was used conduct this study. Participants were given a pretest and a posttest to determine the changes in scientific process skills as a result of participation in the project. The students were interviewed to determine their ideas about science and how those ideas changed over the time of participation in summer camp. Also the students were observed by the researchers, as well as audio-
and video-taped to capture the verbal conversations and debates that take place as a result of discussion of ideas during the program.

Students participated in this study as individuals and group members. Teacher and student interactions were noted to follow three main interaction styles: structured, guided and open-ended. These interactions work much like the inquiry levels described in the literature. Students also interacted with each other in three different ways: independently, dependently, and multifuncting. Some students wished to work alone, while others preferred others to contribute to their work as well.

Finally, there were five main types of science talk described by this study based on Gee’s (1997) four types of science talk: design and debate, anomaly talk, everyday speculation talk, and explanation talk. What was also noted was an overwhelming amount of prior experience talk. Because students were given free choice in their topics of study, many chose to study topics that they had some interest or prior experience with. This led to a comparison of current findings to those they had already anticipated or expected.

This study shows that self-guided inquiry projects require a range of interaction styles between students and also teachers. Many students need differing levels of support in order to be successful. In addition, it is important that students have an opportunity to select a topic of choice so that they have the opportunity to build on their scientific knowledge from their prior experiences.
Dedicated to:

My Mom and Dad &
Aunt JoAnn and Uncle Paul

With love and appreciation for encouraging me to dream and wonder
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CHAPTER 1

INTRODUCTION

Study Background

Several reform movements have shaped the way science educators view science education and the teaching of science. First, *Science for All Americans* (1989) The authors suggested that all students—and adults—can and should have an understanding of scientific concepts and vocabulary to be members of 21st century society. The authors felt that everyday technology was changing so quickly and dramatically that there would be great demand for technological understanding by the lay people of the United States.

Next, the National Research Council, with input from scientists and educators across the country, began developing the *National Science Education Standards* (NSES) (National Research Council, 1996). The resulting manuscript was two documents: *NSES* (National Research Council, 1996) and *Benchmarks for Science Literacy* (American Association for the Advancement of Science (AAAS), 1993). NSES incorporated broad guidelines that state or local governments could use to develop their own teaching standards. *Benchmarks for Science Literacy* listed specific grade levels that certain concepts should be taught in school.

Then, the *Third International Mathematics and Science Study* (TIMSS) was completed and results further pushed reform movements and financial resources for
improvement in science education. TIMMS stated that American high school students fell far behind students from other countries in science learning—American science and math test scores were some of the lowest in the study. Another important finding in the study was that American textbooks covered many more topics than foreign textbooks, repeatedly mentioned the same topics, but did not increase the depth of study about any one subject. With these results, public support and demand for science reform was apparent. One suggestion to improve our nation’s science education, given by Wheatley (1991) prior to TIMSS, is that “concentrating instruction on fewer key concepts could substantially improve science literacy. It would also make room for long-term projects that build kids’ understanding of how science functions outside of the lab” (p. 9). Building a student’s understanding of what science means in an everyday context, instead of memorizing scientific facts, is one way to satisfy the demand for a new understanding of science.

NSES successfully outlines the process skills that students should be involved in as they are learning science content. There are eight categories of science standards in NSES; only three of the eight standards are directly related to students understanding the vocabulary or concepts in science. The remaining five standards relate to the process or changes in understanding the concepts. This exemplifies current science education reform because the majority of standards emphasize learning content, not memorizing content. The standards suggest that teaching by inquiry is essential to learning. This requires that teachers and students be actively involved in
the development of activities (e.g., planning investigations; creating tests; choosing instruments; designing data tables).

The NSES standards allow students to understand the history of the development of scientific ideas, or the inquiry process that took place to mold established concepts, such as the model of the atom, that has changed over time and continues to change today. One standard states:

> It is part of scientific inquiry to evaluate the results of scientific investigations, experiments, observations, theoretical models, and the explanations proposed by other scientists. Evaluation includes reviewing the experimental procedures, examining the evidence, identifying faulty reasoning, pointing out statements that go beyond the evidence, and suggesting alternative explanations for the same observations. Although scientists may disagree about explanations of phenomena, about interpretations of data, or about the value of rival theories, they do agree that questioning, response to criticism, and open communication are integral to the process of science. As scientific knowledge evolves, major disagreements are eventually resolved through such interactions between scientists (National Research Council, 1996, p. 171).

The historical context of the atom (and other scientific concepts) is important because it lets students know that even though the original ideas about the atomic model were incorrect, they were necessary to elicit a discussion and further research about the correct version of the atomic model. Following the guidelines of NSES will ensure that more students understand the process of science and that it is fallible and scientists can be wrong; by communicating with one another, scientists find out what is and is not correct. This sharing of ideas and concerns, in history and practice, is often left out of the science classroom. This problem may be addressed by encouraging more self-guided inquiry learning by students.
One problem that arises from a lack of communication in the science classroom is that students do not have confidence in their ideas or findings (Lemke, 1990). For example, when multiple students are working on the same problem and different results occur, students typically look to their teacher to determine who has the “right answer.” Students will rarely look at their own methods or data to determine if their results are correct. Often, only those who find the expected result have confidence in their work. Traditional, structured types of activities that create these situations are good for developing research skills or basic conceptual understanding, but not for the development of inquiry type learning that builds critical thinking skills.

Students who are involved in designing their own experiments and carrying out the procedures they developed are more likely to believe in their results than that of other classmates (Lemke, 1990). They are not only more likely to have confidence in their findings, but they are more willing to defend the answers they discovered during the process. One reason for this is because students are less sure that there is a “right answer” when they develop the question and procedure. In addition, students are more likely to communicate about their findings if they develop the questions and procedures, because they are more interested and motivated to learn about the concepts. This problem is important because it is more realistic of scientific investigations than structured activities because it mimics the process that real scientists use to learn about our world.

Ideally, inquiry science teaching addresses the importance of communication in science by also helping students vocalize and write about their science thinking and
critical analysis (Lemke, 1990). It is common for inquiry activities to include a range of assessment methods for students to express what they comprehend their experiences. Methods that have been used with some success include logbooks and free writing exercises; however, students are often unsure of what information is necessary for logbook or data keeping records. They are rarely given an opportunity to discuss their questions and ideas or critique the ideas of others, which gives them a false idea about the true process of science.

The I Wonder Process is a teaching method that encourages the “science process skills” of data collection and communication of findings for peer review. The I Wonder Process is an exemplar of how inquiry can be embedded into everyday science classroom activities while maintaining a school district’s curriculum. The teachers who have used the I Wonder Process do so for the likeness to real scientific methods and results. In this project, that will be assumed and the study will concentrate on the unique communication patterns that develop as a result of these inquiry experiences.

Purpose of Study

National education reform movements have suggested methods for teaching science; some methods are currently in practice, yet not necessarily improving scientific literacy in the United States (Bybee & Ben-Zvi, 1998). Scientific literacy goes beyond recognizing definitions; it allows citizens to understand, apply and communicate scientific principles in a technological society. Research is necessary to
define how students successfully build and construct scientific meaning in the microcosm of the classroom. Through a constructivist approach, this research documents a variety of scientific language uses in different settings, concentrating on the unique communication patterns that develop among students as they learn and express their scientific literacy through the I Wonder Process. For ease of interpretation by science educators, specific teaching methods in practice, such as inquiry, will be used in descriptions of this study’s methods and results.

Statement of Purpose

There are multiple methods available to educators to help students learn to use scientific language, however, most students do not reach the level of functional literacy in science. Often what happens is students try to find ways to describe scientific events in their own language and often something gets lost in the translation. There is currently a push in this country to educate individuals to be able to use more scientific language. In the ever-changing nature of our technological society it is important that citizens not only understand science, but also are able to apply it. Science literacy goes beyond knowing the definitions for terms; it is understanding relationships, multiple meanings, and being able to apply these to different situations. Citizens need to be able to distinguish between what is and is not science. National reform movements have suggested methods for teaching science; some are even in practice, yet not necessarily improving scientific literacy. Research is necessary to define how students build and construct scientific meaning in the microcosm of the classroom. Through a constructivist approach this research hopes to document the variety of scientific language uses
in different size groupings such as pairs, small groups and large group settings. In addition specific reform suggestions, such as inquiry, will be applied to help guide this process, therefore, the documentation of this particular practice will be helpful for other science educators as they struggle with helping their students become more scientifically literate.

Summary of Methods

Fifteen 1<sup>st</sup>-6<sup>th</sup> grade students participated in a summer camp program daily from 9:00am-4:00pm for six weeks in which the I Wonder Project was one small part of the daily activities. During each I Wonder Project session, students had an opportunity to share their progress on individual, ongoing scientific inquiry projects with peers and teachers for help or feedback on their methods and reasoning. Students were asked to communicate their findings in several ways: with a paired partner, teacher, or even the whole class. Students wrote about their findings in a structured logbook and final findings report. These reports were compiled into a print version titled the I Wonder Camp Journal (Appendix A).

Pretests and posttests were administered to students to determine changes in scientific literacy skills such as communicating, measuring and estimating. Students participating in the study were interviewed three times to determine what they believed science was, what they were learning as a result of camp participation, and how they would share this information with others.

Once student projects were complete, interview data and sections of audiotape (of student conversations) were transcribed and analyzed as the primary focus of this
study. Student logbooks and final project reports were reviewed and analyzed for supplemental information.

Primary research questions are listed below and included in Chapter 3:

1. How did I Wonder practices, activities, and communications promote the development of a scientifically-literate culture among the students?

2. How do students experience participation as an individual as well as a member of the group at large while working on their self-guided inquiry project?

3. Which aspects of students’ scientific literacy (use of scientific vocabulary in written and oral settings, as well as process skills) changed as a result of participation in the I Wonder Project?

4. How were scientific methods learned, utilized, and transmitted to peers and adults in the classroom through oral language?

Summary of Chapters

In Chapter 1, I have described the current reform movements toward more student inquiry in science education. I have also suggested reasons why this research study is timely and important. In addition, general research questions and definitions of terms to be used throughout the dissertation have been presented.

In Chapter 2, I describe the relevant theory and research related to inquiry, the I Wonder teaching method, as well as other teaching methods. In addition, a review of
situated learning, scientific literacy, culture in the classroom, as well as gender issues in the classroom, are highlighted.

In Chapter 3, I provide a review of the epistemology and theoretical framework that guides this research. In addition, I provide the reader with detailed explanations of the varied research tools that were used to conduct and analysis the data for this study.

In Chapter 4, I highlight the pretest and posttest results showing non-parametric statistically significant improvement in each of the six science process skill tasks. In addition, I share the growth in individual students’ results from pretest to posttest and the inclusion of use of the science process skill in their I Wonder Project when applicable. Also, a recap of the activities used to help students improve their science process skills is described.

In Chapter 5, I provide a pre-assessment of the students’ attitudes and beliefs about and toward science. The students’ ideas about what science is and what scientists do at work are also presented. Next, the chapter describes how these ideas and attitudes were used to guide students toward a different view of science and how as a group the students and teachers build a more scientifically-oriented community.

Chapter 6 highlights individual students’ progress and “lessons” they learned while participating in a self-guided inquiry project. Each of the students had a unique experience and took away something different from the experience: some a change in attitude about science, others in science content, and even growth in their scientific abilities. Six students’ stories are described in detail.
In Chapter 7, I provide information and data describing the individual needs of the participants as they worked individually with the teachers on their I Wonder Project. This chapter describes three main ways that teachers and individual interacted—structured, guided, and open-ended. In addition, students’ peer-to-peer interactions during individual and whole group activities will be described in a later section of Chapter 6.

In Chapter 8, I provide a detailed analysis of science conversation types compared and contrasted with those that Gee described in 1997. In addition, a new category of talk for self-guided inquiry is described in detail for the reader: prior experience talk.

Chapter 9 provides a summary of the findings in each of the main chapters. It suggests five primary keys to successful guided inquiry projects: a scientific community, social interactions with teachers, social interaction with peers, science process skills, and verbal interaction with peers. In addition, Chapter 9 suggests implications of this research for science classrooms and future research endeavors.

Definition of Terms

The following terms and their definitions are described as used throughout this document.

The I Wonder Process refers to the teaching method or inquiry process experienced by students in this study. This includes the skill building activities to increase students’ abilities in regard to science process skills as well as those activities
designed to help students learn to function as part of a scientific community. The phrase “I Wonder” refers to the publications I Wonder Journal for Elementary School Scientists and Great Blue (a later version of the same journal). These publications represent ten years of scientific work by students participating in the I Wonder Process.

Inquiry is a learning process that can involve making observations; asking questions; determining what is already known; planning investigations; using tools to gather, analyze and interpret data; proposing answers, explanations and predictions; communicating the results (NSES, 1996, p. 23). This study refers to a range of inquiry methods:

- **Confirmation Inquiry**, in which students are given a question, methods by which to solve it, and the expected results—this is the least-involved type of inquiry (Tafoya, Sunal, & Knecht, 1980).

- **Structured Inquiry**, in which students are given a question and the methods by which to solve it; they are not given the expected results (Tafoya, Sunal, & Knecht, 1980).

- **Guided Inquiry**, in which students are given a question, but the methods by which to solve it and results must be designed and implemented by students (Tafoya, Sunal, & Knecht, 1980).

- **Open-Ended Inquiry**, in which students determine their own question(s) and methods to determine an unknown result—the most-involved type of inquiry.
CHAPTER 2
LITERATURE REVIEW

Introduction

This chapter introduces the relevant and significant literature pertaining to scientific literacy and how to help cohorts achieve this literacy in the classroom setting. Similar to Chapter One, this chapter is also divided into many sections. The first section describes the theory of inquiry as it relates to the National Science Education Standards (NSES). Following this section is a brief history of the I Wonder Journal and how it relates to inquiry and science literacy. Social constructivism is further elaborated in a discussion of culture and language and their effect on learning. Next, learning in a social context develops the relationship between learning and the social situation where it occurs. Following this line of reasoning is a brief discussion of culture and language and how each are socially developed. Next, is an operational definition and description of scientific literacy. Continuing to build understanding of how to work with cohorts of students is a description of peer collaboration. Finally, classroom discourse and how gender affects this discourse is discussed.
Inquiry

As stated in Chapter 1, many events have led to reforms in science education over the last half century. Recent reforms have stemmed from a need for a more scientifically and technologically literate society. Alberts (2000) states that science is more than just facts to be learned; it’s a critical thinking process. This concept was an important guide for new state and national teaching standards. One teaching method that enables students to learn this process is inquiry. According to NSES, inquiry is:

A multifaceted activity where students: make observations; pose questions; research in textbooks and other reference materials what is already known; plan and implement investigations; use evidence to explain questions; use tools to gather, collect, and interpret data; propose answers, questions, and predications; and communicate findings (National Research Council, 1996, p.22).

It should be noted that NSES and other reform documents state that inquiry is not the only way to teach science: “Teachers should use different strategies to develop the knowledge, understandings, and abilities described in the content standards. Conducting hands-on science activities does not guarantee inquiry, nor is reading about science incompatible with inquiry” (National Research Council, 1996, p. 23).

However, to learn the process skills of science, inquiry (as defined above) is the recommended teaching practice because it resembles the way real scientists practice in their respective scientific fields. Donovan, Bransford, and Pellegrino (1999) suggest that people who have expertise in a given area share several key characteristics:

1. Have a deep foundation of factual knowledge;
2. Understand facts and ideas in the context of a conceptual framework and;
3. Organize knowledge in ways that allow for retrieval and application (p. 12).
Factual knowledge is part of the shared characteristics above but does not comprise the whole, which demonstrates the importance of inquiry as a building block to expertise.

National Science Education standards cite the benefits of inquiry by using research from the field of science teaching. For example, as a result of active engagement in inquiry, students in grades K-4 should be able to:

1. Ask a question about objects, organisms, and events in the environment;
2. Plan and conduct a simple investigation;
3. Employ simple equipment and tools to gather data and extend to the senses;
4. Use data to construct a reasonable explanation, and;

Shymansky et al. (1983, 1990) completed two studies, several years apart, to determine the effects of a new science curriculum, including what was then described as inquiry methods, on student achievement. Researchers found there was an improvement in achievement, attitude, and process skills in some areas of science, but not all. For example, in the area of chemistry they found few significant differences in student achievement between the old and new curricula. They attributed this lack of significance to the traditional nature of chemistry materials, which lacked inquiry methods.

According to Haury (1993), the benefits of inquiry are:

1. Generally enhance student performance, particularly lab skills;
2. Fostering scientific literacy and understanding of science processes;
3. Vocabulary knowledge and conceptual understanding;
4. Critical thinking;
5. Positive attitudes towards science, and;
6. May be particularly valuable in underrepresented populations (p. 2).
Due to the number of benefits it can produce, inquiry is a common term used among educators; a variety of definitions exist. Tayfola, Sunal, and Knecht (1980) define inquiry on a continuum or range of practices from confirmation to guided inquiry. The first type is the lowest level of what can be considered inquiry. It is only stated as such because the students are actively involved in doing an experiment, this type of inquiry is called confirmation. Conformational inquiry was described as an activity assigned to the students where the main task was to prove what is already known (Tayfola et al., 1980). Many students have participated in these types of science laboratory activities. They already know what the correct answer is and are able to change their answers by manipulating data if their observations do not match what they were supposed to achieve. The second type, moving slightly closer to the NSES definition of inquiry, it is called structured inquiry. Structured inquiry provides students with questions, procedures, and information but does not provide the students with the correct or known answer. This type of inquiry has a very important place in the science classroom, especially when students are working with potentially dangerous materials such as chemicals. Students should have a more structured activity so they know which chemicals to add first or how much is appropriate. The final type of inquiry on Tayfola et al., continuum is guided inquiry. This is where the students are given a question to answer, but they may or may not have the procedure, or it may be developed as a class.

Martin-Hansen (2002) adds two types of inquiry to Tayfola et al.’s continuum beyond guided inquiry: coupled and open. Coupled inquiry is a combination of guided
inquiry and open-ended inquiry; students begin with a question, investigate the issue, share results and then based on discussions or personal interest, students engage in open-ended inquiry. *Open-ended* inquiry is when students choose and share a research question and the procedure or method by which they will answer it, including a data collection plan. Definitions of scientific inquiry by Tayfola et al. and Martin-Hansen are combined on the continuum shown below:

**Inquiry Continuum**
Confirmation → Structured → Guided → Coupled → Open-Ended

In order for educators to provide a variety of inquiry methods along the inquiry continuum, they need a classroom environment that can support such changes.

According to the reform document Inquiry and the National Education Standards (INSES) (2000), teaching inquiry should incorporate five major learner guidelines:

1. Learners are engaged by scientifically oriented questions;
2. Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions;
3. Learners should formulate explanations from evidence to address scientifically oriented questions;
4. Learners evaluate their explanations in light of alternative explanations; particularly those reflecting scientific understanding and;
5. Learners communicate and justify their proposed explanations (p. 25).

NSEs lists teaching standards, and imbedded in these standards are ways to create a classroom environment conducive to teaching by inquiry. However, there are a variety of difficulties that educators face when beginning to teach inquiry. Welch, Klopfer, Aikenhead, and Robinson (1981) suggest some common barriers for teachers, the most common being perceived difficulty, especially with classroom management.
Many educators did not learn science through inquiry methods themselves, so they feel ill-prepared to follow the models and meet requirements. If and when teachers attempt inquiry, they see students’ initial confusion and lose confidence in inquiry’s effectiveness. In addition, teachers state that they want to practice inquiry, but feel like they have to teach factual knowledge for their students to succeed in standardized proficiency tests. Pressure from parents not familiar or confident with inquiry, either, may lead to the final decision not to practice it.

However, some teachers have reported great success with inquiry in their classrooms, either practiced individually as student projects or as a teaching method for an entire cohort (Reardon, 2001). It appears that success in inquiry comes from creative and flexible teaching and, most importantly, uses students’ experiences and questions to guide the learning process. Once students begin their research, other questions arise to stimulate their critical thinking. For example, Reardon (2001) makes the following comments about the learning accomplished by her students:

> In both reading and in science I have heard students develop their explanations in the same way: by using additional focused observations, by asking more questions, through feelings, and intuition, through casual reasoning, reasoning by analogy, working from the opposite position, using outside authorities, carrying out research, and I have heard explanations stimulated by community reasoning (p. 10).

With inquiry, students are encouraged to continue the process of scientific inquiry by asking and sharing questions, developing new tests and procedures, writing about science and applying what they learn to old and new ways of thinking.
History of I Wonder: The Journal for Elementary School Scientists

*I Wonder: The Journal for Elementary School Scientists* is the product of an inquiry-based teaching method initialized by elementary school teacher Mark Wagler. Wagler wanted to find a method to involve his students in real science inquiry.

The key he thought, for linking the practice of student and professional scientists was the sense of wonder that scientists have every day as they conduct authentic inquiry. By “wonder” he referred not only to curiosity and doubt, but also to the delightful contemplation of the mysteries of nature (Beeth & Wagler, 1997, p. 3).

Using these ideas as a platform for his new teaching method, Wagler asked his students to make a list of twenty “I Wonders” individually and had each student choose a research project from that list. The students then developed (with the aid of their teachers) a self-guided I Wonder Project. As a member of the Heron Network (a group of elementary school teachers and students in the Madison, WI Metropolitan School District and surrounding area), he shared his successful teaching practice with others, who then adopted this method into their classrooms (Beeth & Wagler, 1997).

As inquiries into student research projects continued, students and their teachers met and updated their classes on their progress and changing ideas (Beeth & Wagler, 1997). Students reported their results at the end of the school year in one of several ways: by presenting their work as a seminar at the annual *I Wonder Conference* for elementary school students, writing a scientific report and submitting it to *I Wonder*, or combining these two options or using an alternative means of communication.
The Heron Network provides students with a scientific community that authenticates their work and familiarizes them with how real scientists research and draw conclusions. “I Wonder: The Journal for Elementary School Scientists\(^1\) is unique in that it provides a mechanism for disseminating elementary students' investigations of science in a form that is analogous to printed journals within the scientific community” (Beeth & Huziak, 2002). Teachers in the Heron Network help students write articles for dissemination—an uncommon genre of writing in most elementary schools—and the journal is distributed annually, in print, to students within the Heron Network\(^2\).

The journal has grown and changed over its ten-plus-year existence; currently, each Heron Network teacher requires his or her students to read past issues of *I Wonder* prior to proposing a new investigation. In this way, students emulate the activities of professional scientific communities by determining the existing body of knowledge before they begin an inquiry project (Beeth & Huziak, 2002).

One example of this process is from a study of taste buds. “Barber (1996)\(^3\) published an article that addressed the question, ‘Where are taste buds strongest?’ This question was posed after reading Gould-Werth's (1995) inquiry article. What was particularly interesting in this case is that Barber actually talked with Alix Gould-Werth about revising the study she published in 1995” (Beeth & Huziak, 2002, p. 7).

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\(^2\) *I Wonder* is available on the Internet at http://danenet.wicip.org/heron/html.

\(^3\) Authors quoted in this section refer to students who published in the *I Wonder* or *Great Blue Journal*.
Barber was able to draw on the knowledge that Gould-Werth had already obtained and actually improved the study to collect additional information.

In addition to communicating with past authors about their research questions, students in the Heron Network have also been encouraged to communicate with students who have similar questions. For example, both Zeng (1995) and Kalfayan (1995) published articles about building materials; they both tested the stability of different materials. Zeng attempted to build cubes with his materials and Kalfayan compared three different materials over time. Both boys were able to communicate with one another about their methods and results, but they were also able to pursue their own interests and conclusions.

According to Bruce Alberts (2000), president of the National Academy of Science, “one skill that all students should acquire though their science education is the ability to conduct an investigation where they keep everything else constant while changing a single variable” (National Research Council, 2000, p. xiii). Methods used by the I Wonder Process can help teachers communicate specific scientific skills such as data collection and variable manipulation. For example, Glover (1996) conducted an experiment in which she compared the heart rates of boys and girls. In her study, she used multiple repetitions of data collection and kept variables (e.g. age) as constant as possible so she could detect heart rate differences by gender. In addition, Glover was able to share insight for future research in the journal, in case another student was interested in the same topic.
When Beeth and Huziak (2002) analyzed *I Wonder* journals published from 1992-2000, they found that students conducted two types of inquiries: “scientific” and “engineering.” Schauble, Klopfer and Raghavan (1991) suggested that when children try to investigate the reason something works, they tend to focus on producing desirable outcomes (often by trial-and-error) instead of using more scientific processes or systematic explorations.

Schauble, Klopfer, and Raghavan (1991) defined engineering as “a goal of manipulating variables to produce desired outcomes” (p. 860). In an attempt to determine the difference in logic between students working on a scientific model of research from students working on an engineered model, the following observation was made:

A child working from a science model could be expected to undertake a relatively wide search of the experiment space by exploring all levels of the maneuverable variables, In contrast, to the extent that a child is working form an engineering model, he or she is concerned with generating a particular result and may therefore focus on variables judged most likely to affect the outcome, overlooking or attending only briefly to those presumed noncausal. The result may be narrower search, that is, generation of fewer of the possible combinations of variables (Schauble et al., 1991, p. 869).

Beeth and Huziak’s (2002) initial analysis of the articles in *I Wonder* from 1992-2000 identified those articles that claimed to use procedures associated with experimental/scientific design and those that used engineered approaches. Analysis of the articles published in *I Wonder* provided an excellent opportunity to see how elementary students responded to inquiry instruction, depending on whether their response was “scientific” or “engineered” in nature. Articles identified as "scientific" or "engineered" were further examined to determine which investigations produced
only the desired outcome and which also generated new scientific knowledge for the author(s).

Inquiry in the classroom can take many forms. On one end of the continuum, investigations can be highly structured by the teacher so that students proceed toward known outcomes. At the other end, investigations can be free-ranging explorations of unexplained phenomena” (NRC, p. 10). Inquiry-based teaching requires a change in the way many science teachers think about science education. The I Wonder Process is just one of many avenues educators can use to help their students participate in a more authentic inquiry experience. The NSES suggests that this change should occur systemically across the nation. For example, one NSES suggestion states: “inquiry-based teaching requires careful attention to creating learning environments and experiences where students can confront new ideas, deepen their understandings, and learn to think logically and critically about the world around them” (p. 73). The I Wonder Process follows this recommendation in a unique and meaningful way for the students.

Social Constructivism

Wertsch (1991) states, “... even when mental action is carried out by individuals in isolation, it is inherently social in certain respects and it is almost always carried out with the help of tools such as computers, language, or number systems” (p. 15). Our culture affects the way we read, move and even think. In addition, Vygotsky (1978) suggests that learning occurs when we begin to internalize
what we have learned in our interactions with others, not in our interactions with tangible culture. Therefore, when researchers are interested in finding out what students have learned, they must be interested in how students have socially constructed their understanding through interactions with peers and others.

Wells, Chang, and Maher (1990) suggest that: “knowledge does not exist in packages that can be transmitted from one person to another... And it has to be constructed or reconstructed by each individual knower through a process of interpreting or making sense of new information in terms of what he/she already knows” (p. 2). In any group of learners, there can be multiple understandings of the same correct idea based on prior knowledge and beliefs. These understandings are socially constructed with other people who are sharing an experience.

Learning often comes from interactions with the natural world, or with our interactions with others. “Whenever learning is dependent on the incorporation of information that cannot be obtained exclusively from the individual learner’s transactions with the physical environment, linguistic interaction plays a crucial role in the process” (Wells et. al., 1990, p. 3). This means that students must not only learn how to use the environment to construct meaning, they must also learn how to use language to aid in their understanding. In order to do so, some students may require the assistance of others such as adults, teachers, or even more experienced peers (Vygotsky, 1978). Sometimes this can happen in one direction where the expert passes his/her knowledge onto the novice through discussion or questions, but the novice must be willing to receive the information (Wells et. al., 1990). More often
however, the community and social environment that the novice and expert are working together in, also play an important role and there is an active and constructive role played by both the novice and the expert. In order for this to take place the “expert and the learner see themselves as fellow members of a learning community, in which knowledge is constructed collaboratively” (Wells et. al., 1990, p. 4). Two important characteristics must exist for this type of collaboration to take place:

1. the teacher does not always assume expertise and authority about the topic under inquiry;
2. whether or not the role of expert is filled by the teacher, and if so whether she or he is interaction in a group or with an individual student, the mode of interaction is that which is characteristic of talk between young children and their parents about a topic of mutual interest (Wells et. al., 1990, p.4).

The result of these characteristics is that the students might have the opportunity to pursue topic of challenge and interest to them individually, as well as pool their individual strengths and weaknesses to help one another. Also, this provides a safe place for students to meaningfully explore based on their own personal experiences. By building communities of collaborative learners students are given a broader opportunity to engage in personal inquiry interests.

Scientific inquiry can be considered social constructivism because students and teachers are learning together, building a knowledge base as they participate in shared activities. Gergen (1995) comments on the importance of social constructivism by
contrasting it to the traditional lecture, which conceals the social processes the lecturer went through to learn the material. “The hours of preparation—the re-reading of texts, scanning of notes, exploration of new resources, discussions with colleagues, trial-and-error presentations in preceding contexts, all of which may be necessary for a consummate lecture—are essentially removed from student view” (Gergen, 1995, p. 31). These processes are all part of the social nature of learning that is not attained in isolation. Gergen (1995) proceeds to challenge, as inquiry does, the nature of teacher as “knower” and students as “minds to be filled” (p. 33). In order to have inquiry, students and teachers must be participants in the action of learning.

Lave and Wenger (1991) claim that “learning, thinking, and knowing are relations among people in activity in, with, and arising from the socially and culturally structured world” (p. 51). Knowledge is socially mediated: what a person believes to know and understand today may be different tomorrow as he or she comes into contact with different people, places and situations. We learn as we participate with others.

In addition to knowledge being socially mediated, it also needs to be socially connected to the real lives of the students. Dewey (1910) stated that students need to be active and creative, constructive instead of passive and conforming. But often adults forget to consider that students have had experiences and these experiences have taught them things about the world that can be applied to their learning. Dewey cautions that young children in particular need to be able to find a tie between what they learn at home and what they learn in school. He states,

These are two great things in breaking down isolation, in getting connection—to have the child come to school with all the experience he has
got outside the school, and to leave it with something to be immediately used in his everyday life. The child comes to traditional school with a healthy body and a more or less unwilling mind, though, in fact, he does not bring both his body and mind with him; he had to leave his mind behind, because there is no way to use it in school (p. 80).

It is important not only to establish what the students bring to school (or summer camp) with them, but it is important also to make sure those prior experiences are part of the school endeavors. Only then will we be able to really reach deep long lasting learning with all students.

Culture and Language

Social constructivism relies heavily upon the understanding and interpretation of language and culture. According to Wink and Putney (2002), “Language and culture are an important focus in the development of positive psychosocial values and academic growth” (p. 79). Language has three functions:

1. The communication of propositional information (also termed the referential, cognitive, or ideational function);
2. The establishment and maintenance of social relationships and;
3. The expression of the speakers’ identity and attitudes (Cazden, 1988, p. 3).

Language use varies by gender, race, community and even individual. Understanding and using the language of a culture allows an individual potential membership in that particular culture. Mehan (1982) states that “language does not occur in isolated sentences, but in natural units of speaking, like speech acts and speech events. Indeed speaking is like other cultural systems of behavior (e.g., religious, economic, and political); it is organized in each society in specific ways that are to be discovered upon analysis by the investigator” (p. 63).
Culture has been defined and redefined over time. LeCompte and Schensul (1999) state that “culture is created in a process as many individuals share or negotiate multiple and overlapping socially based interpretations of what they do and what occurs in local situations. Culture, then, is an abstract construct put together or constructed as people interact with each other and participate in shared activities” (p. 49). On a daily walk through a store, school, or park, one can encounter many different examples of social culture. For example, while watching a parent with two young children negotiate through the grocery store, we can observe the culture of family life and parental limits on child activity. At home, children may be allowed to touch and feel many objects; in the grocery store this behavior is not permitted and this limit is clearly expressed through the language of the parent, “No, you may not touch.” These learning experiences with parents are the first cultural experiences of our young and do not typically include the formal curriculum of school, but participating in them begins to teach us how we are expected to behave, even think, as young adults.

Mehan (1982) states that “culture or civilization, taken in its widest ethnographic sense, is that complex whole which includes knowledge, beliefs, art, morals, law, custom, or any other capabilities, and habits acquired by man as a member of society” (p. 60). We learn how to be part of our society from our earliest moments. Infants begin to learn to talk through interactions with their parents, more specifically with their mother, who acts as a major socializing agent (Dobbert & Cooke, 1987). In the beginning, mothers are willing to accept any response from their
infant and “count” it as conversation. Language is a system of gestures first and a system of words later. As communicators, we are attuned to one another’s gestures, facial expressions and other symbols to recognize when another person is serious, joking, sad or happy; without a system of cultural gestures in place, we would need additional words to describe these emotions. However, as an infant grows, its mother begins to expect it to participate in conversation more and more, not accepting just any sound as language, but searching for specific sounds from the infant until eventually the child learns to talk (Rogoff, 1990). The symbols and words we learn to use at home in the early years evolve as we grow and we spend more time observing the world outside our homes.

Educators are continually coaxing students into a different way of acting and speaking to help students build a culture of academic language. James Paul Gee (2001) suggests that “success in school is primarily contingent on willingness and ability to cope with academic language” (p. 2). Without participation in the learning of academic language, students will not be able to fully participate in the culture of school. The home language is often referred to as primary language, while the language learned during formal schooling is called academic language.

When students adopt a more academic language, they are forced to give up their natural and primary way of speaking; they begin to use larger words, placing them in broader context, and rely less and less upon the casual way of relating everything to the immediate world around them. When students make this transition, they are moving away from primary language (the first learned language; the language
of home) to a broader language for the social context of school (Gee, 2000). Some students never make this transition and do not succeed in the academic environment (Delpit, 1995).

Children also learn through observing one another and playing with members of the same cohort and gender. For example, at elementary school recess, boys may form a large group around the monkey bars pretending the structure is a battleship, complete with head officer. Meanwhile, girls may play in smaller groups or pairs swinging on swings or jumping rope. Tannen (1990) generalizes play for boys as large groups, hierarchically structured with leaders, that have winners and losers. In contrast, girls’ play centers around two or three girls; intimacy is key and there are no winners and losers (Tannen, 1990). Eventually these play relationships permeate into other areas of children’s lives; “There are usually ‘rules’ to be learned related mainly to social roles and to what can and cannot be done” (Dobbert & Cooke, 1987, p. 105).

Play is integral in helping children learn the rules they will need for social life as adults. According to Williams (2000), culture is formed by all human groups. In the adult world, men are often looking for ways to maintain a leadership role and be in charge instead of allowing someone else to tell them what to do. Young men learn that they must take control of a situation early or someone will do it for them. However, young girls learn that they must compromise and share to be included in female activity. Female adults tend to look for social networks and worry about a shift in alliance: compromise with others or be compromised. What we learn about our gender
culture is normal, visible and open for observation (Williams, 2000; Moreman &

When speech and practical activity converge, they provide the tools for
learning based on the culture in which they exist (Vygotsky, 1978). In the United
States, schools are the common denominator for society, so they are left to teach the
discourse of the larger culture. Classroom language includes the study of situated
language use in one social setting. Understanding the everyday nature of conversation
and its differences based on gender can potentially ease disagreements among
students, aid them in problem analysis, and help educators plan lessons and decide
who might work best together.

Learning in a Social Context

Humans tend toward group or cultural participation. Each person or persons
are part of many different social groups and organizations: family, school,
neighborhood. Each of these organizations has their own social behaviors or norms.
Shultz (1976) describes these norms as “thinking-as-usual” or “behaving-as-usual”
assumptions (p. 96). He suggests that there are four main assumptions that hold true
about norms in a group or organization:

1. That life and especially social life will continue to be the same as it has
   been so far; that is to say that the same problems requiring the same
   solutions will recur and that, therefore, our former experiences will suffice
   for mastering future situations;
2. that we may rely on the knowledge handed down to us by parents, teachers, governments, tradition, habits, etc., even if we do not understand its origin and its real meaning;

3. That in the ordinary course of affairs it is sufficient to know something about the general type or style of events we may encounter in our life-world in order to manage or control them; and

4. that neither the systems of recipes as schemes of interpretation and expression nor the underlying basic assumptions just mentioned are our private affair, but that they are likewise accepted and applied by our fellow-men (Shultz, 1976, p. 96).

Shultz goes on to describe the “crisis” which arises when one of these “principles” does not hold up in social life. For example, if a person routinely attended a reading book club and the topics were usually of historical interest and the group decided to begin to discuss a scientific journal instead the person might experience “crisis” because they don’t have the experience or the language to negotiate the new social environment. They are suddenly a “stranger” to the social activity they had learned to rely on. The person has to undergo a process of social adjustment. Similar to these experiences, when students had the opportunity to participate in scientific investigations differently than their typical school science tradition it can also cause a “crisis” until the students learn the new rules and behaviors of that situation.

Others such as Lave and Wenger (1991) and Rogoff (1990) suggest that learning stems from the social situation in which the person was located. Learning occurs as one participates in communities of common practice and traditions. Rogoff (1990) suggests that the social world is the first place for learning and then everything else follows, meaning that, we are social creatures and we rely on our social situations to teach us the appropriate actions. This is further supported by Lave and Wenger
(1991) when they state that situated learning takes as its focus “the relationship between learning and the social situation in which it occurred” (p. 14). They go on to suggest that learning is not a passive process where one can learn something and then later apply it to a real situation. But that a learner “acquires the skill to perform by actually engaging in the process, under the attenuated conditions of legitimate peripheral participation” (p. 14). This is further supported by Dewey (1910), who states that learning does not happen in isolation, but must stem from a student’s own personal experience and be expanded into multiple applications in other experiences. In order to learn science one must participate in scientific activities, not just learn about science from a book or in isolation of other scientific participants.

James Paul Gee (1991) suggests that learning in a social context occurs in one of two ways: through acquisition or through learning.

**Acquisition** is a process of acquiring something subconsciously by exposure to models and a process of trial and error, without a process of formal teaching. It happens in natural settings which are meaningful and functional in the sense that the acquirers know that they need to acquire something in order to function and they in fact want to so function.

**Learning** is a process that involves conscious knowledge gained through teaching, though not necessarily from someone officially designated a teacher. This teaching involves explanation and analysis, that is, breaking down the thing to be learned into its analytic parts. It inherently involves attaining, along with the matter being taught, some degree of meta-knowledge about the matter (Gee, 1991, p. 5).

Most people gain knowledge through some combination of acquisition and learning. Knowledge depends on the context and expectations of the social setting (Lave & Wenger, 1991; Gee, 1991). In some situations it is more important for students gain knowledge through learning, especially when they are talking about their knowledge
in explanations, analysis, and criticisms (Gee, 1991). However, if students are expected to perform some task based on their knowledge it is important that they have had acquired their knowledge through a process of trial and error or by working without formal teaching. When students need to be able to do both, talk about their knowledge and perform using their knowledge they need more than one type of experience and social learning environment.

Gee (1991) describes social discourse or learning in a social discourse as an “identity kit.” This identity kit includes all of the social rules: ways of acting, talking, and even thinking, that make up a group of people or social network. Gee suggests that everyone has a primary discourse, the oral discourse learned in the individual’s family from birth. From the primary discourse, all other identity kits that a person tries to obtain are secondary discourses. In order to obtain an identity kit in a new social group one must begin the task of control and mastery of the language used in that social group. To obtain control one must be able to use, function, and understand the secondary discourse (Gee, 1991). However, to reach a level of mastery, Gee suggests a person must be able to participate in the secondary social discourse with “full and effortless control” (p. 8). Therefore, for students to be successful in school they must be able to control and in many cases master the secondary discourse of formal school language.

In the case of the I Wonder Process, students must be able to manage the secondary discourse of school, and also begin to control the language of science in a broader sense then they learned even in school. Learning or acquiring the secondary
language of science is not an easy process. It requires a complex, social environment where students have the opportunity to learn from formal teaching processes as well as acquire from trial and error and informal activities. Scientific literacy is mastered through acquisition, so students need models in natural, meaningful, and functional settings (Gee, 1991).

Scientific Literacy

NSES (1996) states that “scientific literacy implies that a person can identify scientific issues underlying national and local decisions and express positions that are scientifically and technologically informed” (National Research Council, 1996, p. 23).

NSES also lists four specific goals for students in a scientifically literate society:

1. Experience the richness and excitement of knowing about and understanding the natural world;
2. Use appropriate scientific processes and principles in making personal decisions;
3. Engage intelligently in public discourse and debate about matters of scientific and technological concern; and
4. Increase their economic productivity through the use of knowledge, understanding, and skills of the scientifically literate person in their careers (p. 13).

Note the focus of NSES’s four reform ideas is not for students to memorize content or vocabulary, but to understand and process new information, critically analyze this information, make and defend judgments, and be able to tell the difference between scientific and political information. A scientifically literate person will be able to use his or her knowledge about scientific processes to make personal and public decisions.
about issues that require his or her attention. For example, if the question of what type of power plant to build is raised on the public ballot, most citizens will need to be able to read, understand, and critically analyze scientific documents to make informed voting decisions about their community’s future or to participate in a public debate about it.

To contribute to their community’s economic productivity, citizens need to be able to read, write, and think critically about science and technology issues; jobs are increasingly demanding more critical thinking and processing skills (NRC, 1996). According to NSES’s four reform ideas, a scientifically literate student will also gain personal fulfillment from science and experience the joy of discovery by learning more about their own scientific questions.

To emphasize the importance of mental processing and critical thinking skills as part of the scientifically literate person, Bybee and Ben-Ziv (1998) developed a continuum to describe the evolution of students’ scientific literacy during a 6-week study period, when the “individual develops a greater and more sophisticated understanding of science and technology” (p. 490). There are four major categories of scientific and technological literacy on the continuum. First, and lowest on the continuum is the nominal understanding of science and technology (Bybee & Ben-Ziv, 1998, p. 490). Students in this range can define terms, but have little understanding of relationships between these words and other scientific words or concepts. In addition, often these understandings are combined with misconceptions.
The next level is functional science and technology literacy. The students in this category can read and write science with understanding of the vocabulary. However, they are lacking in understanding of larger concepts of science. The third category is conceptual science and technology literacy. This is where students not only understand the concepts but are able to identify the parts as well as how they fit into the whole of the conceptual understanding. They understand the structure and procedures of the disciplines. The final category is multidimensional science and technology literacy. This combines the conceptual understanding and applies it to the larger picture, like the history or nature of science.

This continuum is important to identify the various stages that students come to the classrooms with and to help teachers guide their planning as they try to move them along the continuum. This continuum identifies the various levels of scientific understanding that students bring to the classroom and helps teachers guide their planning to move students towards multidimensional literacy. It is important to note that NSES (1996) makes allowances for an individual’s strengths and weaknesses within the discipline of science:

Individuals will display their scientific literacy in different ways, such as appropriately using technical terms, or applying scientific concepts and processes. And individuals often will have differences in literacy in different domains, such as more understanding of life-science concepts and words, and less understanding of physical-science concepts and words (National Research Council, 1996, p. 22).

Yet before strengths and weaknesses can be determined, it is essential for students to build connections between the concepts and processes of science and how they
interrelate. Until they can do this, they will continually find themselves not understanding the language of science.

Discussing and sharing ideas with peers and teachers is essential for students to build scientific literacy and be successful in scientific inquiry. The use of science in oral communication gives students time to reflect on what they think in comparison to what others think. The teacher in this situation helps guide students away from misconceptions and allows students to make decisions; in essence, he or she becomes a true facilitator. The students’ process of questioning, designing, experimenting, and communicating begins, ends, and is guided by discussion.

Gee (1997) stresses the importance of student discussions, but warns educators to be aware of how students spend their time in discussion. Gee divides classroom discussions about science into four types, noting their common pitfalls. Design and debate discussion is when students become involved in discussing research methods (e.g., how the experiment was set up; if it was a fair test), but do not proceed beyond how to conduct research. Often, discussions of this type do not lead to scientific understanding because they are not conducted in the planning stage of an experiment; instead, they take place when students are suspicious of methods they’ve completed because of unexpected results. For example, in the following simulated transcript notice how the pair is not talking about science understanding or reasoning, but only about how the experiment was set up.

S-1–Um, maybe if the ramp was smoother the ball would go as far as we predicted.
S-2–But how are we going to make the ramp smoother?
S-1–We could use sandpaper…
S-2–My dad has this thing that he used to sand the wall and it…..
Notice that the students discuss how to change their methods centers on how to make the result fit their expectation rather than on why a smoother ramp might be a better design. The inability to move forward within the science discussion is one reason Gee cautions against this type of talk.

Secondly, *anomaly talk* refers to discussion about an unexpected result, and again, conversation does not proceed beyond this subject to build connections between scientific ideas and concepts. Note the following simulated transcript:

T–We have been trying to grow these plants under a grow light for three weeks. However, only a few of the plants seem to be getting taller. What do the plants seem to be missing that they need to grow?
S-1–Do you think the ones that are the tallest are absorbing all of the light?
T–How would that happen?
S-2–It couldn’t happen because the plants that are growing are all in one spot together. There are separate lights for the other plants, but they are not growing…
S-1–Well maybe they were the better plant seeds and they just would have grown taller no matter what their grow light was like.

Class discussion would proceed to focus on seeds and stray from the lesson of what plants need to grow besides light. This type of anomaly talk is common between students in a classroom setting and is likely to continue until redirected by the teacher.

The third type of discussion is *everyday speculation talk*; students refer to the processes they learned, but reduce it to everyday language or everyday experiences; often the science concepts or processes get lost in the talk. In the following simulated transcript, a teacher is trying to help students use their science vocabulary of “control” and “independent and dependent variables.”
T–Can you explain to me how you set up this experiment?
S-1–We put one piece of fruit out on the counter by the window and left it uncovered and one uncovered in the refrigerator, and one uncovered just in the back of the room away from the window.
T–Why did you choose to put one away from the window?
S-2–So it would be like at home in the kitchen
T–How will you compare the changes?
S-2–We will just look at them and see if they do the same thing or not.
T–Compared to what?
S-1–The one in my mother’s kitchen.

Students have a control and several comparisons, but they are still using the reference of the set-up in their home kitchen instead of scientific experiment terminology. When students resort to everyday talk, it is an opportunity for their teacher to put scientific tags on their language.

The final type of discussion in Gee’s (1997) work is explanation talk; “explaining is, indeed, the deepest sort of ‘making sense’ in science” (p. 12).

However, it is often unused in peer groups because students have not yet developed their scientific literacy. Often, in science classrooms, an experiment happens with little or no discussion of what the students have seen or experienced, yet discussion of an activity is vital to build student understanding.

Lemke (1990) agrees that students need to be given time to talk about science to become scientifically literate. “Teachers should use question-and-answer dialogue less than they do now and organize more class time for student questions, student individual and group reports, true dialogues, cross-discussion, and small group work” (Lemke, 1990, p. 168). With curriculum content demands and time constraints,
though, science teachers often resort to lecturing students about science instead of listening to student ideas about science.

Because scientists (and some educators) use a unique language, Lemke suggests an incremental approach to teaching students how to link scientific terms with processes in complex sentences (1990). Scientists use passive voice and ways of communicating that reduce emotion and personal opinion. To become scientifically literate, students must learn how to write and interpret this new language.

According to Lemke (1990), “students should be taught in great detail, with many models and examples, the parts, order, and meaning relations among the parts of the major and minor genres of science” (p. 171). Minor genres include writing questions or observations while major genres involve creating formal papers or lab reports. Teaching the details of these genres is important in building a culture of scientific literacy.

Application is also important to build scientific understanding. Lemke (1990) states that often students don’t learn science because they can’t make connections between ideas. “Students have to learn how to combine the meanings of different terms according to the accepted ways of talking science” (Lemke, 1990, p. 12). It is important that students be given an opportunity to use their new knowledge in a new, scientific situation. Application of knowledge will help students build the necessary connections between science concepts.

Lemke’s (1990) final suggestion is that “both teachers and students need to see the similarities and differences between commonsense ways of talking about a topic
and the ways science talks about it” (p. 170). Moving students away from Gee’s (1997) everyday speculation talk, when students reduce scientific explanations to common language and experiences, and aiding the students in understanding the subtle laws of science become permissible in their language.

Each of these suggestions is important in establishing the scientifically literate society promoted by NSES (1996). However, if students do not have the opportunity to discuss their ideas, it is unlikely that they will move past a nominal understanding of science.

Draw a Scientist Test

The perception of science and what scientists look like has been a topic of study for several decades. Trying to determine a method to objectively test what a student believed about science and scientists has been developed and refined several times over. The initial study began with Chambers in 1983. Chambers described the purpose of his study as “determining at what age children first develop distinctive images of the scientist” (p. 257). Chambers tests 4807 children in 186 classes from kindergarten to fifth grade (p. 258). He found the following indicators of a standard image of a scientist:

- lab coat: usually, but not necessarily white, eyeglasses, facial growth of hair, symbols of research: scientific instruments and laboratory equipment of any kind, symbols of knowledge: principally books and filing cabinets, technology: The products of science, relevant captions: formulae, taxonomic classification, the “eureka”! syndrome, etc (Chambers, 1983, p. 258).
Chambers used these standard images to compare the drawings by students in different grade levels. He found that the number of indicators, (standard images) increase dramatically with each grade level. The kindergarten students earned a mean of 0.31, whereas the third graders earned a mean of 2.43, and fifth graders a mean of 3.26.

Chambers also made comparisons dealing with socio-economic, gender, and intelligence differences. He found that “the standard image was slower to appear in lower income schools, and in a few such schools the image was almost totally absent until the fourth or fifth grades” (Chambers, p. 260). As far as gender is concerned, only female subjects drew a picture that contained a woman scientist. Finally, high IQ students “tended to produce the standard image at an earlier age in those groups tested for intelligence” (p. 261). However, Chambers did note that all of the higher IQ students were also from the higher economic income level as well. Other interesting results from this study included the fact that in all pictures scientist worked inside, not out of doors. In addition, many students associated science directly with war.

Several follow up studies have been compiled which continue to reiterate the results from the Chambers studies. One example was completed by Newton and Newton (1998), who found similar results with young children but suggest several cautions as a result of their studies. “Some caution is needed in interpreting children’s pictures. Their drawings reflect their stage of development and some attributes may have no particular significance for a child but may be given undue significance by an adult interpreting them. For example, very young children commonly draw bald, smiling faces on potato-like figures regardless of the situation” (Newton & Newton, p.
This statement and others made by the authors caution future researchers to remember that child’s drawing of a scientist may not always be a direct representation of the child’s conception of a scientist. The authors went on to explain what they felt the study did measure.

As an absolute measure, the DAST test may be precise enough indication of the level of awareness of aspects of the popular image of the scientist but as mentioned earlier, a consecutive interpretation. One note of caution having met less restrained interpretations of our won findings, the charm of some children’s naïve pictures can tempt unwarranted conclusions. It also has to be remembered that, whatever pictures tell there will always be things left unsaid (Newton & Newton, p. 1141).

However, the authors did reiterate the findings of Chambers in regard to the gender issues. “Both boys and girls depicted the scientist predominately as male, a tendency which increased with age until, by the age of 10, all the boys and over 80% of the girls did so” (Newton & Newton, p. 1142). In addition, all of the students tended to give their scientist a white lab coat. Even following the students for several years found little change in this particular attribute. However, over time the students did begin to add attributes such as goggles or safety glasses as they were exposed more to school science safety issues.

Another study was conducted to improve the objectivity and interrater reliability of the DAST test. Finson, Beaver, and Cramond developed a specific set of instructions and checklist for raters to use so that students drawings could be interpreted accurately (p. 198). They state the following as justification for these tools: “the scoring of the DAST can be somewhat cumbersome and important stereotypical elements may be omitted during rating and scoring.” The authors continue by stating
that use of “student portfolios, drawings, and rating sheets could provide tangible evidence of perceptual changes over time” (Finson et al., p. 201). The authors also added interview questions to allow students the opportunity to share their own ideas about the drawings without the adult interpretation problem found before.

**Peer Collaboration**

Because peer collaboration has been the main focus of many research studies about attitudes, cognitive performance and even social skill building, there are a variety of definitions and applications of this term. In the quest to understand how children learn and understand, the study of the influence of peers on cognitive development seems vital.

Johnson and Johnson (1975) are the authors of the classic methods text on cooperative learning titled *Learning Together and Alone*. Within the context of definitions by Deutsch (1949), they describe effective learning as

1. Working together to solve problems;
2. Competing with enjoyment and;
3. Working on your own to complete a task (p. 1).

In the cooperative learning literature, the comparison of cooperative methods with competition and individualized instruction is common (Johnson & Johnson, 1975; Qin, Johnson, & Johnson, 1995; Skon, Johnson, & Johnson, 1981). Johnson & Johnson (1975) state that a cooperative goal structure “exists when students perceive that they can obtain their goal if, and only if, the other students with whom they are linked can obtain their goal” (p. 7). A competitive goal “exists when students perceive
that they can obtain their goal if, and only if, the other students with whom they are linked fail to obtain their goal” (p. 7). And finally, an individualistic goal “exists when the achievement of the goal by one student is unrelated to the achievement of the goal by other students” (pg 7). Qin et al. (1995) update these definitions to include the following descriptions: “Cooperation the presence of joint goals, mutual rewards, shared resources, and complementary roles among members of a group. And competition the presence of a goal or reward that only one or a few group members could achieve by outperforming the others” (p. 131).

Lonning (1993) also cites and expands Johnson and Johnson’s (1975) five elements of cooperative learning:

1. Positive interdependence: individual success depends on the success of the group;
2. Face-to-face interaction: students need to interact physically and verbally to maximize the benefits of cooperative groups;
3. Individual accountability: the goal of instruction is for every student to learn the material;
4. Interpersonal and small group skills: skills necessary to function effectively in groups must be taught and;
5. Group processing: feedback on group functioning is necessary to encourage improvement (p. 1089-90).

These skills are important in building the peer dialogue this study addresses. If these elements are not present in group collaboration, not all students will benefit from it.

**Classroom Discourse and Gender**

Tannen (1993) addresses discourse by “framing” conversation based on the circumstances of the communication. Tannen cites multiple frames, such as personal encounters, confrontation and reactions, which are all part of the everyday human
experience, but each conversation is unique combination of frames. “One of the most important influences on all talk (some say the most important influence) is the participants themselves—their expectations about interactions and their perceptions of each other” (Cazden, 1988, p. 67). Not only are we influenced by what is being said, but also by who is saying it—obviously, gender plays an important role in a speaker’s identity or perceived identity. For example, women find themselves sharing things with girlfriends they wish they could share with their spouses or boyfriends, but they don’t feel validated in those conversations the same way they do with other women who have shared similar experiences (Tannen, 1990).

Tannen (1990) refers to “public and private speaking” in regard to gender. For example, women tend to dominate private discourse one would find at home or in a coffee shop (Tannen, 1990). But in public discourse found in classrooms and business meetings, it is men who dominate conversation; boys tend to yell out their responses while girls are willing to wait for their turn to speak. Therefore, same-sex groupings to consider new ideas or difficult problems offer more benefits to students than mixed groupings because students have an opportunity to express their ideas and concerns on a familiar platform and to be heard. Furthermore, classroom conversation that is mainly dominated by boys may be accepted by inexperienced teachers because this behavior is culturally acceptable.

Typical conversation styles between boys and girls also differ, beginning at a very young age (Tannen, 1990). Boys tend to give orders while girls make suggestions. Psychologist Jacqueline Achs and her colleagues, studying preschoolers
ages two-five, found that girls made proposals for action by saying “Let’s,” whereas boys often gave commands (Tannen, 1990, p. 153). For example, in playing doctor, boys said: “Lie down” or “Get the heart thing” (Tannen, 1990, p. 153). These conversational styles in small group settings can affect the working relationship peers have with one another; Whorf (1956) suggests that some words may have completely different meanings within the same culture. For example, “Let’s” sounds like a suggestion to most women, but to men it is often heard as a command. These subtle but important differences set the tone for group decisions.

Schools provide places for the boys and girls socially accepted behaviors to reenact themselves (Scribner & Cole, 1973). Not only do we learn the rules for gender in school, but also the rules for being citizens or nationals (Cohen, 2000). The purpose of cultural transmission is to help us know how to think, act and feel appropriately in our culture (Spindler, 2001). Schools are where culture is explicit; we must learn how to take turns, raise our hands and even learn how to jump in a conversation and be heard to become effective citizens.

“We have to consider how the words spoken in classrooms affect the outcomes of education: how observable classroom discourse affects the unobservable thought processes of each of the participants, and thereby the nature of what all students learn” (Cazden, 1988, p. 99). Again, reflection on personal practice is important to determine how our actions as educators are contributing to the overall context and discourse of the classroom setting and subsequently our culture.
Conclusion

This chapter has reviewed the different types of inquiry and its application to the I Wonder Project. Benefits for teaching in this way as well as common concerns with inquiry were also addressed. The need for having a scientifically literate society and the learner objects for obtaining this type of society were also reviewed.

The reviewed research will serve as a basis for this study as it strives to describe the unique nature of interactions, conversations, and learning accomplished by the students when given the opportunity to participate in a self-guided project.
CHAPTER 3
RESEARCH METHODS

Introduction
Qualitative research methods were used to conduct this study within the researcher’s epistemology and conceptual framework. Results from quantitative data analysis served as supplemental information. Included in this chapter are the questions upon which this study is based, descriptions of the methods/theories used to develop these questions, and the defining elements of the I Wonder Process.

Research Questions

1. How have I Wonder practices, activities, and communications promoted the development of a scientifically-literate culture among the students?

2. How do students experience participation as an individual as well as a member of the group at large while working on their self-guided inquiry project?

3. Which aspects of students’ scientific literacy (use of scientific vocabulary in written and oral settings, as well as process skills) change as a result of participation in the I Wonder Project?

4. How were scientific methods learned, utilized, and transmitted to peers and adults in the classroom through oral language?
Epistemology

The nature of learning as part of a cohort of learners illustrates in part the social nature of school. All human actions are meaningful and thus the descriptions of these actions are important. As cohorts act together, they are constructing their own culture and therefore their own meaning. Because cultures are produced within the understanding of the social world (Lincoln & Guba, 2000), I chose to ground this research in social constructivist epistemology. As cohorts act together, they are constructing their own significance in the world and subsequently their own culture. This social production of learning is of interest in this research. As a researcher, I was interested in describing the social action and conversations that took place among students as they engaged in the social production of their scientific knowledge.

This study focused on the verbal and social interactions of students, captured in-person and during tape recordings, as they completed individual science inquiry projects. My interest was to interact with the participants long enough so that I accurately portrayed the work done by the participants as they together made meaning out of their shared experiences. Important in these descriptions was the use of participant’s language. According to Schwandt (2000), “language is understood as a range of activities in which we express and realize a certain way of being in the world” (p. 198). Important in these interactions was the participants’ use of language. The description of these events in this work was from the participants’ point of view, using participants’ words to describe the activities whenever possible.
Conceptual Framework

Too often science in the classroom is portrayed as “all-knowing” or “irrefutable.” Science is more than a body of facts discovered in a laboratory. Students leave school with the vision of scientists as old white men, with disheveled hair, goggles and lab coats. The I Wonder Process (elaborated in the next section) guided students towards constructing a view of science where, they themselves can be scientists. The I Wonder Process guided students through the steps of asking questions, researching possible answers, designing experiments or fair tests, analyzing the data they collected, and finally giving them several methods of communication to share what they learned as a result of their scientific investigations. Through the I Wonder Process, the students will construct their own culture or community of scientists striving for a more realistic understanding if what science is and is not.

Teaching science in the classroom is often likened to teaching a foreign language, with the added difficulty of rapid change in the language: the new terminology of science grows daily with our culture’s ever-changing understanding of science. In order to help students make sense of this new scientific language, it is important to submerse them in the culture of science. LeCompte and Schensul (1999) state that culture is created in a process as many individuals share or negotiate multiple and overlapping socially based interpretations of what they do and what occurs in local situations. Culture, then, is an abstract construct put together or constructed as people interact with each other and participate in shared activities (p. 49).
When students have the opportunity to participate in shared experiences, they will be able to construct their own scientific culture or community. Chapter 5 details how the students participating in I Wonder were aided in building a scientific community. When students participate in activities that are developed to help them function like scientists, their attitudes and views about science may change from those of intimidation and confusion to informed thinking and inquiry. If this change occurs within a connected group of people, they establish their own beliefs and attitudes that define their culture: “Culture consists of the beliefs, behaviors, norms, attitudes, social arrangements, and forms of expression that form a describable pattern in the lives of members of a community or institution” (LeCompte & Schensul, 1999, p. 21). A scientific culture uses the processes of science to wonder, explore, and search for answers to the questions that drive humans to exist the way that we do.

The purpose of this study was not to promote the I Wonder Process as the correct way to teach science, but to explore how this method may help students understand their culture and create scientific meaning for themselves. The teachers who are part of the Heron Network have continued to use these teaching methods for over ten years. Over the years additional teachers and students from nearby areas also join the Heron Network. The teachers have not only continued to adapt and expand I Wonder, they have also used similar methods in other subject areas such as mathematics, social studies, and literature. The focus of this dissertation is not to add to these methods, but to study the social and verbal interactions of the students as they engage in the I Wonder Process.
This study focused on the social action that builds or leads to the scientific language used in our culture: how scientific literacy is learned, utilized, and transmitted to peers and adults in the classroom through verbal and social language. Because of the nature of these data, data were analyzed primarily with qualitative methods (with supplemental use of nonparametric quantitative statistics), mainly ethnography. “Ethnography takes the position that human behavior and the ways in which people construct and make meaning of their worlds and their daily lives are highly variable and locally specific” (LeCompte & Schensul, 1999, p. 1). Therefore, results from this study were applicable to this particular population of elementary school students in a camp setting, but the methods employed through the I Wonder Process follow national education standards that are applicable to most American classrooms.

According to Kathleen Wilcox (n.d.), an ethnographic study of school environments needs to “attempt to make the familiar strange, to notice that which is taken for granted either by the researcher or by the participants, to assume that that which seems commonplace is nonetheless extraordinary and to question why it exists or takes place as it does, or why something else does not” (p. 458). I was in daily social contact with students (as students participated in I Wonder projects and other science camp activities) to gain a sense of how I Wonder fit into their daily language of learning and growing into a group culture. Also, the short time frame of the summer camp required early community-building activities so that participants could begin to build trusting relationships with one another, as well as with researchers: “When
investigator and participant build a trusting relationship, together they create a safe and open environment in which the voices or opinions and views of the participants emerge in an authentic way” (LeCompte & Schensul, 1999, p. 12). Some of the students also did not trust their individual science skills so building a trusting relationship with the individual students was important for their success.

Scientific “literacy” has become a buzzword in the science education community. National standards of education recommend that science educators help students study science in the same manner real scientists do, so they may become scientifically literate. However, most scientists don’t work on research ideas in isolation like students in a typical science classroom setting, but with partners and groups. Together, scientists build on a theory by helping and challenging one another and posing alternative explanations for the same results. This type of interaction often is left out of the science classroom for many reasons: lack of time, a teacher’s lack of subject knowledge, or fear of losing control of the classroom environment. The conceptual premise of this study was that students, like scientists, build culture together. How students talk about their scientific thinking and understanding is vital to educators’ understanding of how to teach them to become scientifically literate people capable of processing new information.

**The I Wonder Process**

In the classroom, scientific facts and theories are often portrayed as “irrefutable” and scientists as “all-knowing.” The I Wonder Process encourages students to view science as a dynamic body of knowledge that they can contribute to
themselves, as scientists. The I Wonder Process guides students through the steps of asking questions, researching possible answers, designing experiments, analyzing data and communicating results. Through the process of I Wonder, students construct their own culture or community of scientists that strives to understand and better our world.

The I Wonder Process is based on an ongoing inquiry method used by a group of teachers (the Heron Network) in the Madison, WI Metropolitan School District (Beeth & Wagler, 1997). The purpose of the I Wonder Process is to promote scientific discourse among elementary students and through publication of their research in a journal, similar to the scientific discourse within a community of scientists (Beeth & Huziak, 2002). Students of teachers in the Heron Network work on open-ended inquiry projects for the entire school year. As a culminating activity, they publish their scientific findings in the I Wonder section of Great Blue.

Using the I Wonder Process, students who participated in this project began their projects by creating a list of questions they were interested in investigating (a detailed description of daily activities is provided later in this chapter). Participants had the opportunity to research and brainstorm their questions by reading past issues of I Wonder and Great Blue documents online and in original text format. Each student selected one question from his/her list to answer.

Next, facilitators guided participants through the research process required to answer a scientific question. They taught this process through “in class” projects that the entire group worked on together. Each phase of research was discussed and
practiced as a large group: determining methods, gathering research materials, setting up and conducting experiments and recording results and communicating observations.

As students began investigating their individual questions, a topic board maintained by the entire group was made available for posting communications (Wells, Chang, & Maher, 1989). The topic board listed student names and their respective questions, research methods, and other pertinent information such as data already collected and additional areas of interest. Students were encouraged to make changes to the topic board as their project methods and theories changed. To put peer collaboration and scientific discourse in practice, students were asked to check the topic board and ask other students for suggestions and problem-solving techniques before they requested help from a facilitator.

Students completed their projects over a 6-week period. Three times a week, they were encouraged to meet and share information with a regular group of three or four students working on similar projects. Twice during the camp period, all of the students were asked to participate in a scientists’ meeting and share their current progress (including frustrations and success).

After the first focus group interview session, students participated in individual interviews with researchers (Appendix B) to explain factors that influenced their scientific process and thinking. Participants were asked to elaborate on several areas of the I Wonder Process: design, investigation, prediction/hypothesis, interpretation of

\[4\] I Wonder articles are being published currently as part of the journal Great Blue.
data, justification for accepting or refuting the prediction/hypothesis, and writing scientific articles.

Finally, an I Wonder Conference was held at the end of camp for students to share their new scientific knowledge and understanding with the camp counselors, teachers and parents who were able to attend. Students presented their research in five-minute presentations based upon their journal manuscripts. They were encouraged to use visual aids and were recorded on video. All student manuscripts were bound in a journal that was copied and distributed at the conference.

Setting and Participants

The I Wonder Project for elementary students was held during the summer of 2002 at an extended campus of a large midwestern university. The day camp university was 6 weeks in length due to university and local school schedules. Participants who attended camp participated in I Wonder sessions, as well as various academic and social activities such as arts and crafts, as well as process drama performances, at no cost to the participants.

The study area consisted of a main classroom, several other classrooms, and a library resource room (all located within three main buildings), where students searched for information on the Internet and in age-appropriate books that were available for the use of the pre-service teachers to borrow. The I Wonder Project portion of the students’ day was more of a “lab” science setting rather than the outdoor education science setting, like some of the other activities during camp. Students
worked on their individual projects in a location of their choice within the main classroom. These became designated study locations for the duration of the project.

Camp was held daily from 9:00 a.m.-4:00 p.m., Monday through Friday. I Wonder sessions were held five days per week for a minimum of one hour per session; the two small groups participated at different times during the week. As a large group the students worked together daily on different skill-building activities for a minimum of 45 minutes at least three of the five days during the first three weeks of I Wonder camp, in addition to the other meeting times. Individual participants were given additional time if needed (e.g., data collection for a project that required daily observation). In Table 3.1 a brief overview of activities during the six-week period is highlighted.

58
<table>
<thead>
<tr>
<th>Week</th>
<th>Monday</th>
<th>Tuesday</th>
<th>Wednesday</th>
<th>Thursday</th>
<th>Friday</th>
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<tr>
<td>Week One</td>
<td>Pre interview</td>
<td>Pre interview</td>
<td>Tasty bugs-(PS)⁵</td>
<td>Lost on the Moon (TB)</td>
<td>Drops on a Penny (PS) Statue of Liberty (PS)</td>
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<td>Pre process skills test</td>
<td>Pre process skills test</td>
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<td>Week Two</td>
<td>Statue of Liberty (PS)</td>
<td>Big Foot (PS)</td>
<td>Measurement Challenge (PS)</td>
<td>Questions (CB)</td>
<td>Owl Pellets (PS) (CB)</td>
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<tr>
<td></td>
<td>Read articles of I Wonder (CB)</td>
<td></td>
<td>Statue of Liberty(CB)</td>
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<tr>
<td>Week Three</td>
<td>Flashing Balls (PS) Questions (CB)</td>
<td>Design IWP scientist’s Meeting (IWP)</td>
<td>How much water in a baby’s diaper (PS)</td>
<td>ACME Volume Exchanger (PS) (CB)</td>
<td>Bounty Activity (CB) Midterm Interview</td>
</tr>
<tr>
<td>Week Four</td>
<td>Leaf Collection (PS)</td>
<td>IWP set-up</td>
<td>IWP Skittles activity (PS)</td>
<td>No camp</td>
<td>IWP Scientists Meeting (CB)</td>
</tr>
<tr>
<td>Week Five</td>
<td>IWP data Parachute activity (PS)</td>
<td>No IWP time</td>
<td>IWP data</td>
<td>IWP data</td>
<td>No camp</td>
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<tr>
<td>Week Six</td>
<td>Last day for IWP data</td>
<td>IWP articles Post process skills test</td>
<td>IWP articles Post process skills test</td>
<td>IWP articles Final interviews</td>
<td>I Wonder Conference</td>
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Table 3.1. Calendar of activities during the I Wonder Process

⁵ Note-(CB) is a community building activity, (PS) is a science process skill activity, (TB) is a team building activity, and (IWP) refers to the I Wonder Process.
The population of the summer camp included 17 elementary school students from areas surrounding the branch campus. The students were from a variety of socioeconomic status/cultural backgrounds. Students were registered to attend grades $2^{nd}$-$6^{th}$ for the upcoming school year and ranged in age from 6-12 years of age, with a 4 male to 11 female ratio. A flyer was sent to nearby schools to advertise the summer camp. When parents called to express interest in camp activity, descriptions as well as research project descriptions were mailed to the parents. If the parents returned consent forms agreeing or not agreeing to allow their students to participate, they were registered for the free camp. All of the parents who registered their children signed the research consent forms (Appendix C). In addition to I Wonder studies, students were subjects of several research projects and classroom teaching situations for elementary pre-service teachers that allowed the participants to have additional experiences with scientific activities outside of the I Wonder Project. Due to family obligations and/or time constraints, two students could not attend the entire 6-week session; these students were not replaced, therefore, the total number of students completing the program was 15.

Participants were grouped into two groups based on age and skills as demonstrated on pretests. All of the students participated in the same skill building activities together, but were split into two groups for individual I Wonder Projects so that they could have more work space and teacher attention. After the first week of camp, the students began to think about their individual I Wonder Project ideas. After
I Wonder Project ideas were confirmed, the students were further divided into dyads according to social compatibility and project focus. These small groups were necessary for easier facilitation and small group interaction. Student projects that had similar focus areas (e.g., living organisms) were paired together when possible so that collaboration between students and comparisons between projects could be made.

One primary facilitator throughout the I Wonder Process led students in daily activities and helped students begin their self-guided projects. The researcher’s primary role was to observe, however, I often participated as the primary teacher or teaching assistant during large and small group activities. When I participated in activities, I made an effort to record in my field notes whenever possible. Face-to-face interactions between students and the researcher occurred daily through activities, interviews and even meals.

Study Timeline/Activities/Data Collection/Project Deadlines

Week One July 8-12

Monday July 8th, 2002–Students completed science process skills pretest individually, one-on-one with the researcher. Half of the students completed pre-I Wonder Process interview questions, also one-on-one with the researcher.

Tuesday July 9th, 2002–New students attending camp completed science process skills pretest. Remaining students completed pre-I Wonder Process interview questions.
Wednesday July 10\textsuperscript{th}, 2002–First I Wonder Process Skill building Activity—“Tasty Bugs”. Tasty bugs were insects made out of fruit, vegetables, and candy. The students worked in groups of four and each table had a set of “food resources” to use to complete the directions given to each individual. There were a total of eight tasty bugs and each person at a table made a different insect. Before students were allowed to eat their individual insect they were asked to make a list of similarities and differences between the different insects. While the students were eating we combined the characteristics on the board in a list of common characteristics of insects.

Thursday July 11\textsuperscript{th}, 2002–Today, the students worked on a team building activity to help the students learn to work individually as well as part of a team. The activity was called “Lost on the Moon.” Lost on the moon begins with a teacher delivered scenario stating the astronauts had crash landed on the moon and needed to get back to the mother ship. Individual students were asked to rank 15 items from most important too least important for survival back to the mother ship. Then students were asked to discuss with their table groups and come up with the rank order for the group. The students needed to be able to justify their own rankings, and work together to come up with a group list everyone could agree on. Then each of the groups shared their ranking with the class. NASA’s suggestions and ranks were then shared with the whole group.

Friday July 12\textsuperscript{th}, 2002–Today, we concentrated on two different activities, one a prediction activity and the other setting up a controlled comparison activity. First, the students completed the “how many drops of water on the penny” activity. The
students were shown a large drop of water on a penny and were asked to predict how many smaller drops were part of the large drop. The students recorded their predictions. Next, they were asked to predict how many drops of water they could fit on the head of the penny without any running off. Most students predicted 2-5. The students were given cups of water and pipettes and asked to count the number of drops they could get on the head of the penny. There were a variety of results so the class then began to discuss the need for common language or techniques with the pipettes. The class became proficient at arriving at similar number of drops once everyone agreed on the method to use.

Next, the students began the step-up for the “Statue of Liberty” activity. The Statue of Liberty activity was selected to serve two purposes: to allow students to develop better observational skills, and to help them learn the scientific method of setting up a controlled comparison experiment. The students and teachers had a large group discussion about the students’ prior experiences with seeing or looking at pictures of the Statue of Liberty. Next, the students were asked to try to explain why the Statue of Liberty was green. The students came up with several possibilities and these possibilities were tested using copper pennies, iron nails, salt, vinegar, and water. The students set up a controlled comparison experiment by comparing the effect of three different environments (dry, wet, and salty-acidic) on three different
materials: penny alone, nail alone, and penny and nail together, for a total of nine
different possibilities. The experiments “sat” over the weekend for observations on
Monday.

Week Two–July 15-19th

Monday July 15th, 2002–Students made observation of the Statue of Liberty
activity results. Students were given a data table in which to write their observations.
Results were shared and students began to compare and contrast results between
groups. Additionally, the teachers worked individually to help many of the students be
more descriptive in their observations of each of the nine cups.

Next, the students participated in a scavenger hunt activity. Students were
given past copies of I Wonder and they had to find articles about specific items such as
plants, animals, electricity, and other creative or interesting articles. Students shared
these finds with the entire group. As a group, we discussed interesting experiments
that other students had completed. Next, the researcher described the opportunity for
the camp participants to create their own I Wonder Project and asked the students to
begin to think about ideas they might have for their own project.

Tuesday July 16th, 2002–Today, the students worked on a measurement
activity called “Big Foot.” The teacher\textsuperscript{6} and researcher helped students individually
learn how to measure their own foot, by measuring their own shoe. Next, students

\textsuperscript{6} One of the camp counselors, JoAnn, served as the main teacher facilitator for I
Wonder. However, the other two camp counselors occasionally participated as
teachers as well.
were given reproductions of pictures of other animals’ feet. Students had to try to guess what the animal was and measure the length and width of each of the animals’ feet.

Wednesday July 17th, 2002–Today, the students participated in a “Measurement Challenge” where they continued to learn how to use the meter stick and triple beam balance. Then, there was a competition for which group came closest to accurate measurements of different objects around the room.

Next, the students made additional observations of the Statue of Liberty results and changes over time. This time they were asked to create their own data tables to represent their observations of the different cups.

Thursday July 18th, 2002–As two small groups, the students and researcher read through additional past examples of *I Wonder*. Students were asked to make a list of ten questions they might have about science that they would like to learn more about. The students recorded these questions in their student log book.

In the afternoon the students tried to design snail races to determine if snails see color. This question stemmed from one of the *I Wonder* articles were the student asked if fish could see water. The students had ready access to snails in their indoor camp room so this experiment was easy to set up.

Friday July 19th, 2002–To continue to build observation, sorting, and communication skills, “Owl Pellets” were dissected by students. The students were asked to make observations about the materials that made up the owl pellets. They were also asked to sort the material that came out of the owl pellet into piles of like
objects. Finally, the student were asked to write a story describing how they thought
the owl obtained the bones and fur in its stomach.

Week Three July 22-26

Monday July 22\textsuperscript{nd}, 2002–The skill building activity for today was the
“Flashing Balls” activity. The students were shown a translucent ball that would begin
to “flash” and make noise when two exterior metal tabs were touched simultaneously.
The students were asked to create drawings to try to explain what was inside the ball,
and how it worked. The students worked in pairs to complete the drawings. A whole
class discussion was held while students compared their drawings and explanations
with others. Students were given the opportunity to agree or debate the explanations of
others in a friendly manner.

Students were given time to look at the I Wonder Journals and to add to their
list of ten questions they have about science. Most students were able to come up with
a list of ten by the end of the session.

Tuesday July 23\textsuperscript{rd}, 2002–Students spend time in the morning deciding on a
question and beginning to plan their investigations. Then, the first “Scientists’
Meeting” was held. Students had an opportunity to meet with one other “scientist” to
share questions, ideas, and concerns. Each pair reported their discussion to the rest of
the group. Each student selected a single refined question to study after discussion
with teacher and the group at the scientist meeting.

Wednesday July 24\textsuperscript{th}, 2002–Prediction skills were built when the students
participated in the “How Much Water in a Baby’s Diaper” activity. The students were
given graduated cylinders and containers of water. They were asked to add 100 ml of water at a time, then turn the diaper over to see if any leaked. At the first leak, they had to stop adding water. The teacher asked students to predict how much water the baby’s diaper could hold. Many of the children had younger brothers or sisters, so they didn’t think very much! The students were very surprised to note that a baby’s diaper could hold over 1000 ml of water. The experiment was repeated using salt water, and then only 300 ml of water would stay in the diaper.

Next, students were asked to decide on a final material list for their individual project. These lists were reviewed one-on-one with the researcher, and additions and alternative suggestions were made to some of the students at this time.

Thursday July 25th, 2002–The students were still having difficulty understanding what kind of information should be recorded in their science logs, so the “ACME Volume Exchanger” activity was added to aid students in learning how to recognize and record scientific information. 500 ml of water was poured in and 3000ml of water come out. The students were asked to draw a representation of a machine that could be housed inside the box that could do something like that. The students created labeled drawings to represent their ideas.

Friday July 26th, 2002–The activity “Is Bounty really the quicker picker upper?” was used to continue to work on measurement and observation skills. Students had to determine the area of the paper towel by measuring the sides of each of the three different types of paper towels. Next, the students added 10ml of water at
a time until they believed the towel was saturated. They determined which towel would hold the most water, and then compared that to the price.

During the afternoon session, the researcher met one-on-one with the students to administer the Midterm I Wonder Process Interview Questions.

**Week Four July 29-August 2nd**

Monday July 29th, 2002–In order to work on students’ sorting skills, they participated in a leaf collection around campus. The students then worked in four groups to sort the leaves by observable properties. The students discussed why they separated the groups in the ways that they did. Then, the groups shared their sorting method with the other groups and each group tried the others’ methods. The whole group discussed how it was possible to have four different methods to sort the same group of objects.

Tuesday July 30th, 2002–I Wonder Project set-up, predictions, and initial observations. Students were separated into two small groups. One group stayed with the camp counselors while the other students worked on their I Wonder Project for about 45 minutes and then the groups switched. During I Wonder time the students began to set-up or collect data depending on their individual projects.

Wednesday July 31st, 2002–In the morning, students were given I Wonder Project investigation or data collection time. Again, the group was separated into two smaller groups for more individual space and teacher-student interaction.

In the afternoon, the students completed a prediction activity using Skittles. The students were asked to predict how many total Skittles were in the package. Next,
the students were asked to predict how many of each color in the bag. Then, the students were allowed to open the bags and record the number of total Skittles and of each color. They compared the actual number to their predictions. Then, we collected data from every pair and determined the average. The students found they were closer to the average number than the actual number.

Thursday August 1st, 2002–no meeting; gas leak at building.

Friday August 2nd, 2002–In the morning, each group met for 45 minutes to work on project data collection and recorded findings. In the afternoon, there was a scientist meeting to discuss early results, challenges, concerns, and to get help from peers.

Week Five–August 5-9

Monday August 5th, 2002–In the morning, there was time for I Wonder data collection. Most of the students began to ask additional questions, as they have already recorded data for their original question.

In the afternoon, the whole group participated in the “Parachute” activity using different parachute material: wax paper, tin foil, colored cardboard, or plastic zip lock bags. This gave the students another opportunity to participate in a controlled comparison activity.

Tuesday August 6th, 2002–No I Wonder time; researcher not at the site.

Wednesday August 7th, 2002–In the morning, each group met for 45 minutes to work on project data collection and recorded findings. Students were encouraged to
continue to explore when they felt they were done. Other students were asking about additional materials to continue their data collection in different ways.

Thursday August 8\textsuperscript{th}, 2002–In the morning, each group met for 45 minutes to work on project data collection and recorded findings. In the afternoon, more time was made available for those students who required additional time for completion.

Friday August 9\textsuperscript{th}, 2002–Summer camp cancelled because there was no electricity in the building.

Week Six August 12-16

Monday August 12\textsuperscript{th}, 2002–Last day for data collection. Some students worked in computer lab to type their final reports for the I Wonder Conference. They were given a set of questions to guide their writing process (Appendix D).

Tuesday August 13\textsuperscript{th}, 2002–The students were asked to clean up their I Wonder projects today. Everyone worked at computers to type their final I Wonder articles at different times of the day. During the afternoon, students each created a drawing that represented I Wonder Camp to become the cover for their journal.

Half of the students takes final science process skills posttest.

Wednesday August 14\textsuperscript{th}, 2002–Everyone worked at computers to type their final I Wonder articles. Afternoon–Predictions activity–“What does a candy core look like?” The other half of the students takes final science process skills posttest.
Thursday August 15th, 2002–Students finish up with their articles. I combine them and add clip art to finalize *I Wonder Camp Journal*. Students participate in final interview. Student log books are collected.

Friday August 16th, 2002–Final I Wonder Conference. Students participate in final interview.

**Data collection**

Several levels of data collection took place. Through the use of interviews, field notes, and video and audiotapes, communications and behaviors of participants were accurately portrayed for analysis. Audio and videotapes were copied and logged daily; all transcriptions (including those of field notes) were entered into word processing documents. To supplement this information, students’ written work and skill tests were used to illuminate the ways in which they built a scientific culture in the classroom and applied their new language to actual processes and projects in science.

During the I Wonder process, the researcher was actively involved as a participant observer, engaging in questioning and answering as a teaching assistant, but not as formal group facilitator. Field notes were recorded in the researcher’s notebook to record student behavior such as responses to questions or, more commonly, student interactions. For example, if a student worked alone and suddenly wanted to communicate and confirm his/her observations with another student, this behavior would be recorded in the researcher’s field notes. The field notes served as
records to analyze and also detailed times/locations on audio and videotapes to review for further analysis. Separate records (research logs) were maintained daily to outline activities, experiences and general communication patterns observed. Researcher field notes were also used to record the limitations and biases of the researchers themselves (e.g., recording the perceived influence of the researcher’s presence on student interactions). Lincoln and Guba (2000) refer to this type of record as reflexivity, the process of reflecting critically on the self as researcher, the “human as instrument” (p. 183). This was important in tracing the impact of the researcher’s interest and possible interference with the I Wonder Process. Camp counselors maintained similar logs so that events could be analyzed from multiple perspectives.

The classroom setting is primarily social in nature. To observe and understand the changes that student groups underwent required study of their language and conversational patterns. Silverman (2000) states, “the social work is a pervasively conversational one in which an overwhelming proportion of the world’s business is conducted through the medium of spoken interaction” (p. 821). To record student conversations, I set up a video camera in one corner of the main classroom where I Wonder sessions were held. The videotapes were not transcribed in their entirety, but were used to further analyze research field notes and body language among students.

“Although talk is sometimes seen as trivial (‘mere talk’), it has increasingly become recognized as the primary medium through which social interaction takes place” (Silverman, 2000, p. 821). The major focus of this study was to discover the communication patterns and changes in types of science talk among students. The
large group sessions and small group individual investigations were audio taped for I Wonder’s 18 sessions. These audiotapes were transcribed and served as records of individual and group communication.

Focus groups (referred to with students as “scientists’ meetings”) are a method that relies upon the systematic questioning of several individuals simultaneously (Fontana & Frey, 2000). Large focus groups were based on a series of basic questions to help guide discussion (Appendix E). Fontana and Frey (2000) suggest that group interviews are helpful in the process of “indefinite triangulation” by putting individual responses into a context (p. 651). When the students met as a large group for focus interviews, the group was both audio and videotaped. Audiotapes were transcribed.

Interviews were important to aid the researcher in understanding the meaning participants derived from their experiences (Siedman, 1998). Participants completed three structured interviews: one at the beginning of camp, one following the first focus group interview and one during the final week of camp. I asked each of the remaining 15 participants the same questions (Appendix B). Interviews were hand scripted and audio taped for later transcription. The first two interviews were used as a primary source of information about preconceived notions about science, areas of interest in scientific study, attitudes toward science, experiences with science, and how students communicate scientific knowledge to others. The final interview posed similar questions, but also gave students the opportunity to speak about the meaning of the I Wonder Process to them and the changes, if any, they underwent during I Wonder
camp sessions. These interviews yielded supplemental data about student knowledge of the nature of science and which educational activities the students found valuable.

Student logbooks were collected to gain further information on the meaning derived by students from their I Wonder experiences and to follow changes in their written scientific language. Logbooks contained a combination of guided questions to answer and blank pages for extra data, thoughts and notes. Students were not required to write in their logbooks, but were asked to demonstrate project results, which could easily be recorded in the logbooks. Logbooks were not transcribed, but were coded and considered external documents.

Pretest and posttest tasks analyzing students’ science process skills were based on tasks developed by Robert Lonning (1993). Lonning (1993) used content and science process skills to evaluate student learning before and after a science unit where all the students participated in the same activities. Because of the nature of the I Wonder Process, only the process skills tests were used because of the wide range of possible content areas chosen by the students. There were six tasks (observation, classification, measurement, estimation, prediction and communication) students performed before and after participation in the I Wonder Process (Appendix F).

Students worked individually and were guided by a researcher; each test was video taped for record accuracy but was not formally transcribed. Each student produced written sentences or drawings and products as documentation of his/her test. A rubric was used to determine the total score for each task and the totals were combined for an overall score. Scores were determined for individual student tests by
counting the number of correct responses in each of the six tasks. The scores were then analyzed by using the Wilcoxon Signed-Ranks Test, a nonparametric test. A nonparametric test is used when the sample sizes are small, and/or the statistical procedures do not require assumptions about the shapes of the underlying distribution. Because the total number of participants was 15, it was necessary to run a nonparametric test.

The Wilcoxon Signed-Ranks test includes procedures that are distribution free, or require a ranked ordering of subjects. “Significance levels for certain nonparametric tests can be determined regardless of the shape of the population distribution since they are based on ranks” (Norusis/SPSS, 1990, p. 219). The Wilcoxon incorporates information about the magnitude of differences. To calculate the Wilcoxon Signed-Ranks test the differences in scores are ranked. “The sums of the ranks for positive and negative differences are then calculated” (p.220). From these scores a significance level is assigned. From the results of the significance level a rejection of the hypothesis can be determined.

Data analysis

In conversation, meaning is based on how things are stated; while speaking, we do not follow formal grammar rules or pronounce all words properly. Audio data were transcribed as closely as possible to actual camp conversations that took place,
accounting for such instances as timing, pauses, overlaps and intonation. These contextual messages were important to record because they gave listeners/readers clues of the intended purpose of the speaker’s language and how others perceived his/her message. Important meanings derived from notations were included in analysis and results.

All transcripts were sorted into chronological order and categorized according to major themes. Initial analysis was completed according to Erickson’s (1986) methods: “the researcher searches back and forth through the entire recorded corpus for instances of frequent and rare event, moving as it were back and forth through time and space to identify analogous instances” (p. 145). The goal of this process was to identify a particular set of statements, activities or instances that illustrated the development or change of scientific language and process skills in either individuals or groups of students. Pretest materials were immediately evaluated for levels of scientific literacy so that same-ability student pairs and interest groups could be established at the beginning of camp.

Erickson (1986) reminds researchers that even if most cases fit an assertion it is still important to show those instances that do not and to analyze them. Through this process, researchers look for “key linkages” or items that are of central significance to the major assertions that they want to make (Erickson, 1986, p. 147). These key linkages may be short passages or long paired conversations; in either case, they help connect “data as analogous instances of the same phenomenon” (Erickson, 1986, p. 7). This style of transcription is commonly used by conversational analysts such as
Therefore, along with major categories and trends in data, coding and analysis of negative or discrepant cases was completed to illustrate multiple meanings that were established among different students. After multiple iterations of the transcripts, major assertions were located and supporting documentation was sorted under these assertions.

Data was also analyzed for Gee’s (1997) four levels of science talk: design and discovery debate, anomaly, everyday speculation, and explanation. In addition, a new category was identified and explained through student conversations in transcript.

Data from video tapes was viewed and coded for reference, but not fully transcribed. Work from students’ logbooks were analyzed for student’s communication skills, data collection, and also individual learning modes. Some student work is included as examples throughout the dissertation to show the range of abilities and interests of the students.

Pre and posttest data were compared to discover if these scores were significantly different, indicating that the I Wonder process had a positive or negative effect on students’ scientific literacy. Pretest scores of students absent at the posttest were not analyzed. Scores were first compared with a nonparametric test for test means by using the Wilcoxon Matched-Pairs Signed-Ranks Test.

Trustworthiness

According to Lincoln and Guba (1985), there are several criteria for establishing trustworthiness in a scientific study: credibility, transferability, dependability, and confirmability. Credibility was established in this study with repeated observations of the same sample population engaged in similar activities over a 6-week time period. In addition, weekly visits to students while they were engaged in other camp activities helped researchers gain an overall perspective of the meaning students derived from non-scientific activity. Embedded in data collection were methods for triangulation from a variety of researchers and data sources; final analysis was reviewed with I Wonder teachers and counselors.

Transferability of findings involves a thick description of events, activities, and participants (Lincoln & Guba, 1985). Because this research was conducted in an informal summer camp setting, similarities and differences with a formal, traditional classroom were considered to later define areas of transferability. (The I Wonder Process is based on teaching methods suggested by the national reform standards).

Limitations

There were several limitations to this study that must be considered with its implications. First, because participants volunteered to attend an educational camp, the sample population was not a cross-section of the school/community it represented. Also, the range in age of students allowed for mixed-age partnering that would not normally occur in formal schooling (e.g., a fifth and sixth grader working together). The third limitation was the short time frame of the study; not only was 6 weeks a short time for many students to conduct and analyze their own research (I Wonder
projects usually last 9 months), but it was also the minimum amount of time suggested for an ethnographic study of this type (LeCompte & Schensul, 1999).
CHAPTER 4
STUDENTS SCIENCE PROCESS SKILLS BEFORE AND AFTER I WONDER

Introduction

Each of the fifteen students was evaluated on how s/he performed six science process skills, before and after participation in the *I Wonder Project*: observation, classification, measurement, estimation, prediction and communication. As will be discussed in Chapter 7, each of these skills is important in developing self-guided inquiry and overall scientific literacy. “In the vision presented by the *Standards*, inquiry is a step beyond “science as process”, in which students learn skills such as observation, inference, and experimentation. The new vision includes the “processes of science” and requires that students combine processes and scientific knowledge as they use scientific reasoning and critical thinking to develop their understanding of science (National Research Council, 1996, p. 105). However, in order to aid the students in combining scientific knowledge and skills, the researcher and teachers needed to understand the skills that each of the students had prior to beginning camp to be able to help them individually or as a group as necessary. “Students’ ability and inclination to solve problems effectively depend on their having certain knowledge,
skills, and attitudes” (AAAS, 1993, p.282). Problem solving skills for young children include asking questions, making and recording observations, stating reasons for findings, and being able to measure (AAAS, 1993). Six specific age-appropriate skills were selected for the expected summer camp participants.

Each of the six science process skills (observation, classification, measurement, estimation, prediction and communication) is an integral part of developing scientific literacy and to be able to complete a self-guided inquiry project. The individual nature of students’ past experiences or lack of experiences proved to be problematic initially for immediate beginning of the self-guided I Wonder projects. The students’ lack of science process skills (explained in this chapter) and the their lack of experience working with other students during science investigations (explained in Chapter 5) were two major obstacles to self-guided learning.

The researcher focused on several results in this chapter: (a) students’ process skills prior to participating in the I Wonder process; (b) how process skills were taught in I Wonder camp; (c) how students practiced process skills in I Wonder group and self-guided projects; and (d) students’ process skills after participating in the I Wonder process. Each of these observations served to illuminate how students’ science process skills increased as a result of participation in I Wonder Science Camp. Also shown in this chapter is the individual nature of the students’ abilities and the changes in these abilities over the six-week time period.
**Observation and Comparison**

For purposes of this research, *observation* was defined as using one or more of the five senses (feeling, smelling, hearing, seeing, and tasting) to describe an object or group of objects. Students were asked to observe two items: a stuffed animal shaped like a cow and a living violet plant. Students were given a short period of time to observe the objects and ask questions to clarify the task. They were told they could look, touch, smell, and listen, but they could not taste the items. Then they were asked to verbally state as many observations as they could about the properties of each item. In Table 4.1 below the individual students are illustrated by age, total number of verbal observations, as well as the number of comparisons between objects. Also note that there are no common trends related to age or gender in Table 4.1.
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<th>Participant Name and Age</th>
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Table 4.1: Comparison of age, number of observations, and total comparisons during pretest observation task.
Students were expected to use one or more of their senses to provide qualitative observations, as well as counting to provide quantitative observations. During the pretest, a range of observational abilities was noted; eleven of the fifteen students made observations about each item separately without comparing the two by observation and listing likenesses/differences between two different objects. Anna and Anthony represented different levels of proficiency present in observation process skills. Anthony (age nine, grade five) represents a student with good observation skills because he was not only able to state multiple observations, but he was able to draw simple comparisons between the two objects being observed. Anthony contrasted the texture of the two items by saying the “cow feels fluffy, but the plant feels prickly.” He went on to compare other properties: “this one [plant] is alive, but this one [cow] is not alive…it [plant] is what it is, while this one is acting like a cow, made to look like a cow” (pretest notes 7/9/02). In contrast, Anna (age 10, grade 5) stated that the cow “feels like it has beans in, and it was floppy.” When describing the plant she said it “feels fake, fuzzy, and like plastic” (pretest notes 7/8/02). Only four students drew simple comparisons between the two items in the pretest.

As shown in Table 4.1, girls and boys both made comparisons usually hand-in-hand with a larger number of general observations. The total number of observations did not increase with age of the students. The nine-year-olds produced the greatest number of observations. What was unexpected was the drop in number of observations on the part of the older children. None of the student observations involved any observations of quantitative nature. In addition, only one student used smell to make an observation during the pretest. In
general, observations during the pretest came mainly from the sense of touch or sight, which may have been the first types of observations that came to students minds. The students who used other senses tended to spend more time with the objects and made a greater number of observations, usually using sight and touch first.

To further illustrate the magnitude of range in observation ability, Jeff’s pretest observations will be illustrated to demonstrate poorer quality observational skills for a 3rd grader. Jeff was unable to describe the two objects, but he used the objects as prompts for him to share what he knew about cows and plants. For example, after observing the stuffed cow, he was asked to make observations about its properties that he could see or touch. He responded: “milk comes out here.” Observing the violet, he stated: “you need to put water, sunlight and air in for it to live, there is food in the flowers” (pretest notes 7/8/02). Either Jeff did not understand the instructions (hence scientific vocabulary (e.g., observe; describe; compare) or he was unsure of how to make a basic observation based on the five senses.

To teach observation skills, each of the camp counselors frequently asked students to describe what they saw, felt or tasted during meals and other non-structured camp activities. This repetition of observations helped students become aware of the range of possibilities (e.g., touch, sight, counting). In addition, during structured skill-building sessions, students participated in several activities that engaged them in observation and making comparisons between like objects. One such activity was “Why Is the Statue of Liberty Green?” Teachers asked students a series of simple observational questions about the Statue of Liberty to encourage discussion on
proper observation techniques, since seemingly simple questions can yield many answers. For example, “What color is the Statue of Liberty?” was answered with a variety of color descriptions such as “greenish-blue,” “yellow-green,” and “green.”

The following transcript depicts a discussion about the location of the Statue of Liberty. The teacher’s goal was to encourage students to be descriptive with observational data and understand the importance of providing multiple answers and information sources in science, because it can lead to participation by more than one student:

T-So someone who has been to the Statue of Liberty tell me where she sits. Where is she? What’s surrounding the Statue of Liberty?
Anna-Water.
T- Water. What kind of water is that?
Ken-Holy?
Karen- Ocean?
T-Ocean. What do we know about the ocean water that is different than drinking water?
Ariel- Salt water.
T- Salt water. So, what do you think would be different about the Statue of Liberty? You all told me that she was green or blue or gray, but I just told you that she’s made out of copper so why don’t we see the copper? (tape recorded 7/12/02).

Early in the transcript Anna supplied the correct answer, water, but the teacher was looking for a more specific answer: “what type of water”. Two students (Karen and Ken) offered suggestions about the type of water that surrounds the statue. The teacher continued to build detailed information on the correct answer (“ocean”) and asked students to describe the difference between ocean water and drinking water, which lead to the answer of their research question (“why is the statute of liberty green?”).

This type of guidance portrayed the expectations of a scientific setting and helped
children begin to observe, in detail, on their own. The teacher provided scaffolding
necessary to move the students forward in their observation and reporting skills.

Another area where students were encouraged to develop their observation
skills was during individual I Wonder Projects. When discussing how to describe his
mold project, Jeff showed improvement in understanding how to compare two objects:

Jeff-I’ll check on them and see if something happened to it.
TH-Ok, and what happens if something happened?
Jeff-Then, we check the others.
TH-Ok, are you going to draw a picture, maybe?
Jeff-Yea, use the right colors.
TH-Can you describe what happened? Are you going to have to date them, what
happens, your observations?
Jeff-Yea. Like the chip one moldy, November the 2nd, or the cheese one, nothing, January 11. (tape recorded 7/23/02).

Jeff responded to the teacher’s question about what would come next in his research
(if he found a change in data) with “we check the others.” In one sense, he suggested
that one change in data may indicate other changes, but he was also suggesting that the
change might have indicated a valid contrast among data. Later in the same transcript,
when describing how he would record his observations, Jeff said he would compare
two different items with different results, much like he had learned to do in the Statue
of Liberty laboratory activity with the other students.

By the end of the I Wonder Project, all students showed improvement in their
observational process skills. Because data was not normally distributed due to the
small number of participants (N = 15), the change in participants’ process skill scores
from pretest to posttest was compared by using Wilcoxon Matched-Pairs Signed-
Ranks Test (a non-parametric statistical test). Table 4.1 shows the number of

86
observations and number of comparisons made by each participant during the posttest. The number of observations and the number of comparisons increased significantly from pretest to posttest ($Z = -3.086 \ p < .002$).

In posttest results, all students (100%) increased the number of observations they made about the two items. For instance, Jeff showed dramatic improvement in his posttest results. While observing both the stuffed toy cow and the violet plant, he made a significantly greater number of observations, (from three to 14) and was able to contrast the two items. For example, he said, “the cow feels soft and smooth, but the violet feels fuzzy;” “cow is black and white, and the violet is pink, green, brown and white” (posttest notes 8/13/02). These observations were considered an increase in observation skills because he was able to state properties of the objects instead of perceived use of the objects.

Another change from the pretest that was noted in 11 of the 15 posttests was the use of quantitative observations. Recall that none of this type of observation were suggested by any of the students during pretest tasks. Anna demonstrated improvement when she stated: “the cow has three legs with spots and one without…the plant has many dark green leaves, but 13 of them look like they might die because of brown spots on them.” In the posttest, 100% of the students were able to make at least one comparison between the two objects, while only four made such observations in the pretest.
The second science process skill task students were asked to complete was a sorting task. Students were asked to organize 16 objects into at least 3 groups that would make sense to another student or adult. Many items were the same object in different colors. Three groups were chosen as a minimum so students would sort items into like groups instead of random groups.

Students were expected to be able to sort the items into at least three groups. Next, the students should have been able to suggest at least two alternative methods for sorting. Table 4.2 below shows the pretest and posttest scores for each of the students with regards to number of additional methods of sorting they could list.

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8 Objects included: paper clips (4 different colors), screws (different sizes plastic and metal), plastic airplane spoons, round wooden ball, round candy balls—blue and white, plastic suction cups, square wooden piece, poker chip, trash bag twisty ties (3 different colors), nuts, and bolts.
<table>
<thead>
<tr>
<th>Participant Name and Age</th>
<th>Pretest number of additional methods for sorting</th>
<th>Posttest number of additional methods for sorting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tabitha- 5</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Jen- 8</td>
<td>5</td>
<td>17</td>
</tr>
<tr>
<td>Jeff- 8</td>
<td>3</td>
<td>14</td>
</tr>
<tr>
<td>Ken- 8</td>
<td>6</td>
<td>11</td>
</tr>
<tr>
<td>Terry- 8</td>
<td>20</td>
<td>26</td>
</tr>
<tr>
<td>Tina-9</td>
<td>6</td>
<td>13</td>
</tr>
<tr>
<td>Ariel- 9</td>
<td>11</td>
<td>14</td>
</tr>
<tr>
<td>Anthony- 9</td>
<td>16</td>
<td>30</td>
</tr>
<tr>
<td>James- 9</td>
<td>12</td>
<td>17</td>
</tr>
<tr>
<td>Anna- 10</td>
<td>5</td>
<td>12</td>
</tr>
<tr>
<td>Jane- 10</td>
<td>9</td>
<td>17</td>
</tr>
<tr>
<td>Teresa- 11</td>
<td>11</td>
<td>16</td>
</tr>
<tr>
<td>Nancy- 11</td>
<td>4</td>
<td>11</td>
</tr>
<tr>
<td>Anita- 11</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>Karen- 12</td>
<td>5</td>
<td>11</td>
</tr>
</tbody>
</table>

Table 4.2: Number of additional methods for sorting by individual student.
During the pretest, three students chose to group by four colors: white, red, blue and green. Eight students grouped by the four primary item types such as: paper clips, screws, plastic utensils and wooden objects. When asked to justify their groupings, 10 students were unable to explain their sorting criteria. For example, Teresa, sorted the items by their primary function. She named the groups by their function, but when she was asked why she grouped them that way, she responded, “that was the only way I could see to do it” (pretest notes 7/8/02). 14 out of the 15 students were capable of sorting into at least three groups as directed, but 10 were incapable of communicating why their organization would make sense to another person. Students were given the opportunity to regroup or classify the items; only two students were able to list two or more methods. In contrast to those students who did not resort, Ariel suggested that she might regroup by shape, as shown in the following transcript:

TH- can you think of any other ways to regroup or classify these items Ariel?
Ariel- Yeah
TH- can you show me or describe one or more ways for me?
Ariel- well you could take these four square ones and put them together, and these round ones
TH- but what would you do with the remaining items?
Ariel- they would be you know, what’s the word? Not a shape, irr something? Irregular? (tape recorded, 7/02).

Notice that Ariel had to be prodded to give an example of a new sorting system. When she did, she needed to include a large portion of the items in a catchall group of “irregular.” This might suggest that even those who could state another method of sorting still had some difficulty.
Students were given the opportunity to further develop their sorting skills through participation in several activities. For example, leaf identification keys were used to help students develop their classification skills and to demonstrate how groupings can be justified. Students collected several samples of different-looking leaves from plants and trees around campus so that each group had a similar set of leaves to sort. In small groups, students described the major properties of their leaves. Then, as a large group, students decided how to separate leaves into two groups; further groups were compiled in small groups of students. The following transcript describes a debate in a small group (of four) that is discussing how to categorize two types of leaves:

T- what do we do with these purplish leaves and these green leaves?
Anthony- they are the same shape so they go together
Anna- they are different colors so they are different
T- well we have two different opinions, what do the rest of you think?
Tabitha- let’s take a vote
T- why don’t we think about it a little before voting, does anyone see any other characteristics that might help us decide?
James- the veins in both leaves spread out like fingers, but I don’t remember what that is called. (tape recorded 8/29/02).

The students proceeded to decide that the “leaves might be from a similar species of tree or even the same tree, but one is younger and hasn’t turned purple yet, so they grouped them together.” (tape recorded 7/29/02). This experience was important to help students learn how to use common properties to sort.

During individual I Wonder Projects, five students chose sorting as one of the primary components of their self-guided research and gained additional experience through their own projects. For example, Terry and Jeff each sorted mold that s/he
grew according to color, then explored whether difference in color indicated different types of mold or not.

Because of these experiences, the researcher felt that the students would have been able to sort in different groups and be able to suggest multiple alternatives. By the end of the *I Wonder Project*, all students were able to construct at least one classification system as part of their posttest, which was only a change for one of the nine year-old students. Fourteen of the students could create two or more logical sorting methods to organize the 16 items into 3+ categories, as opposed to two of the students in the pretest. The common alternatives students suggested were sorting items by color, size, shape, texture or function.

One example of this change can be seen in Ariel’s work. Ariel was able to re-sort items by a different category: “what they do…they hold things, make things and can be used to play games with these items.” For Ariel, these items weren’t considered in their surface context any longer (by color or shape), but for their functional meaning. Three other children also suggested this method of sorting. One student, Anthony, suggested that items be separated by material (e.g., plastic, wood or metal). Anthony’s thought process as shown below represents a different view of what was typical of student’s abilities. However, the following transcript highlights a brief verbal discussion about how this child made his decisions.
T- what about the paper clips? They have a colored covering over them.
Anthony- I (pause) I have to think about which is more the plastic or the metal.
T- Why do you think that?
Anthony- Well to have three piles I have to make a decision, but I need to think about it more. I will work on the game pieces while I think about it.

(transcript cut, about four minutes later in the conversation)

T- okay AM, we are back to the paper clips. What are you going to do?
Anthony- We could take off the plastic and it would still be a paper clip made out of metal. So I am going to make it a metal.
T- what do you think a scientist would do?
Anthony- Just what I did, or they might ask for permission to have another group, I don’t know. (tape recorded 7/9/02).

During the posttest, students’ behavior indicated that they focused on individual items’ characteristics that may not have been initially apparent during the pretest. Because most students could justify multiple classification patterns instead of one in the posttest, it appears there was overall improvement in this process skill. By opening up their observations to alternative likenesses among objects, such as recognizing multiple differences between the stuffed cow and the violet, students demonstrated an ability to accept and explore answers beyond their own knowledge and “prejudices,” thus increasing their scientific literacy. The ability to sort and the number of additional ways to sort increased significantly from pretest to posttest ($Z = -3.130$ $p < .002$).

Measurement

The process skill task of measurement utilized two instruments: the meter stick and triple beam balance. First, the teacher held up the meter stick and asked the students to identify the object. Next, they were asked to determine the height of a
chair; then they were asked to describe their methods and results. Second, students were asked to identify the triple beam balance and determine the mass of a rock; then they were asked to describe their methods and results.

Given the wide range of ages, I expected that some of the students would have more accurate measurements than others. All of the students could identify the ruler and knew it could measure height, yet nine were unfamiliar with the metric system, as both English and metric units were represented on the ruler. For instance, Jane (age 10) called the meter stick a “yardstick.” She knew one side of the ruler represented inches, but could not remember what units were on the other side. She measured the height of the chair correctly by putting one end of the ruler on the ground, then looked at the numbers near the top of the chair. However, when she realized that she had measured the chair in non-English units, she flipped the ruler onto its other end so she could measure the chair in inches (pretest notes 7/9/02). Five of the fifteen students took their measurements using the metric side of the ruler, but reported their results in inches or feet (e.g., a measurement of 100 centimeters was reported as “100 inches”). Because the metric system is the only measurement system internationally recognized, it is the system scientists and national educational standards recommend be taught, as well as the measurement system used on the state proficiency tests.

Other students were unable to properly hold and measure using the meter stick. For example, Tina (age 9), took the zero end of the meter stick and placed it at the top of the chair. Next, she angled the meter stick away from the bottom of the chair,
instead of straight up and down. She gave a reading of 29 inches\textsuperscript{9}. She made three common mistakes for the students who had little prior practice with the meter stick. First, she placed the zero end at the top of the chair instead of at the bottom of the chair (pretest notes 7/8/02). Six other students made this same mistake. Second, she angled the meter stick so that her results were the actual length of the meter stick. Three other students also made this mistake. Finally, she used the English side of the meter stick instead of the metric side. Six students relied on the English side of the meter stick for their results during the pretest measurement task.

Almost 100\textsuperscript{\%}\textsuperscript{10} of the students were unable to identify the triple beam balance, and only one student, Anthony, was able to use the balance to obtain the mass of the rock, even though he had never used one before. He found the correct mass, 112 grams, by precisely (and correctly) measuring in hundreds, then tens, then ones. It should also be noted that he stated the correct metric units (pretest notes 7/9/02). Several students tried to operate the balance, but were unsuccessful. Others did not put forth effort to use it and like Karen simply stated, “I don’t know how” (pretest notes 7/8/02). It was also common for these students to question the value of this measurement activity, a major theme noted when students didn’t understand a new activity of any type.

Due to the confusion noted with the meter sticks and apparent lack of experience with the triple beam balance, remediation activities were planned for I

\textsuperscript{9} Actual height of chair was 102 cm.

\textsuperscript{10} Fourteen of them were unable, the remaining participant called it a “balance beam or something.”
Wonder camp sessions. As a group we discussed the importance of utilizing the metric system. This was done through a conversation about how scientists all over the world, speaking many different languages, needed to communicate findings to one another. They use the same system, the metric system. Many students simply needed a reminder on metric terminology. Others needed more guidance prior to beginning activities so practice measurements were completed; as a large group, students discussed what might have contributed to varying measurements for the same objects and how to improve the methods leading to these results.

Next, students were placed into groups of three and given two sets of items to measure: one set for height and one set for mass. Each student had to measure each item at least twice and record their results; then each group averaged their members’ results. The teacher determined the correct results prior to group work so all group results could be compared to the correct ones; for motivation, the group with the closest average to the correct measurements won a prize. Peer collaboration and adult guidance were used to help students learn proper measurement techniques. Almost all students needed individual help learning to use the triple beam balance. Approximately 60% of students were able to properly use the meter stick when guided by a minor tutorial at the beginning of the activity, which was an increase from 25% during the pretest measurement task.

Measurement was inherent in most I Wonder activities; meter sticks, specifically, were used in several camp activities and individual projects (especially those involving living plants or animals). After the remedial training session
previously described, the triple beam balance was available for individual projects only; two students (Jen and Karen) requested to use one. Jen used a triple beam balance to compare the masses of different substances (silly putty, slime) she was collecting. Karen used the triple beam balance in conjunction with a meter stick as she monitored the growth of carrots and bean seeds in different salt concentrations.

In general, student scores in measurement improved from pretest to posttest. Students remained adept at using the meter stick, and improved their scientific vocabulary in regard to metric units; however, several students did not fully adopt the metric system into their methods. For example, when Jane was asked to identify the meter stick, she still called it a “yardstick” as she did at the pretest. However, she proceeded to measure the height of her chair correctly and stated 78 “centimeters” as her final reading (8/14/02). Tina called the meter stick a “ruler” and stated measurements in both centimeters and inches. She was able to correspond metric units with metric terminology, but struggled in choosing between it and the English system to describe her results. However, she did use the meter stick properly, by standing it straight up and down instead of at an angle as she did in the pretest (posttest notes 8/13/02). During the posttest, there were still two students who used the English side of the meter stick with no regard to the metric side at all. They both obtained accurate, but non-metric, measurements.

Unit terminology was a greater problem with the triple beam balance because many could not cite the appropriate units (grams). However, twelve students improved their scores because all but two successfully operated the instrument. Karen and Ken
those who demonstrated below-average skill with the triple beam balance, were absent the two days we worked with the instrument. Karen went to the 100’s first, then moved to the ten’s second, and finally made adjustments on the one’s row. But she quickly became frustrated at this level and said, ‘I shake too hard,’ but she continued to adjust slowly and carefully (Posttest notes 8/13/02). Ken tested each row individually first, working from the tens to the hundreds, in an attempt to use trial and error. When he was unsuccessful at obtaining a mass, he gave up (posttest notes 7/14/02). This was typical behavior from the pretest, when students had little to no experience with a triple beam balance, but not from posttest activity. However, researcher notes show that Ken was not present for the skill building activity using the triple beam balance, and this might explain his pretest-like performance on the posttest. After the practice activities and the practical application during individual projects, students showed a significant improvement \((Z=-3.339, p<.001)\) in their ability to take accurate measurements and use the triple beam balance.

**Estimation**

For purposes of this study, an estimate was considered a calculated, abstract judgment about an approximate measurement. Students were asked to estimate the number of M&M’s® in a clear plastic container. After they stated an estimate, students were asked to explain their method and/or suggest an alternative, perhaps more time-consuming, method of estimation (without actually counting the candies).
The students were expected to be able to state a reasonable estimation and provide an explanation for their reasoning. In the pretest, 100% of students understood the concept of estimation and were able to make one. However, only 40% of students could explain their own methodology beyond guesswork. For example, Anna estimated the number of candies to be between 50 and 100. When asked how she came to that conclusion, her response was: “I just gave it my best shot” (pretest notes 7/8/02). However, other students were methodical about their estimations. For example, another student, Terry, explained her reasoning. When Terry was asked why she estimated 200 candies, she responded: “I’ve filled a container with something bigger, so I take that minus the size I know this is and that is what it would be” (pretest notes 7/9/02). In other words, she used her prior experience to help her estimate the total number. Since she had used an entire package of M&M’s to fill a larger container, and knew the number of pieces it contained, she knew her estimate should be less than that number. Table 4.3 shows the range of those students who were able to state a reason versus those who could not by age.
<table>
<thead>
<tr>
<th>Number of Participants by Age</th>
<th>Number of students able to state a reason at pretest</th>
<th>Number of students able to state a reason at posttest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age 5 n=1</td>
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<td>0</td>
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<tr>
<td>Age 8 n=4</td>
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<td>Age 9 n=5</td>
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<td>Age 10 n=2</td>
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<td>Age 11 n=3</td>
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<td>3</td>
</tr>
<tr>
<td>Age 12 n=1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 4.3: Students’ ability to state a reason for their estimation by age during pretest.

In order to aid students in developing reasoning skills to work in conjunction with their estimation skills, students completed several skill-building activities. One skill-building activity students completed involved estimating drops of water. Students were shown a penny with a large drop of water on its surface; they were asked to estimate how many small drops of water formed the large one. After each of the students had an opportunity to “guess,” they were then asked to write in their logbooks why they thought their number was the correct one. Students particularly enjoyed this activity because it was easy to “test” their estimates quickly with a dropper, cup of water and penny. Finding the correct answer was a powerful learning tool that proved...
important to students, as none of them utilized estimation during their self-guided projects—they were more interested in “correct” answers.

In general, students began to apply some of the methods for estimating that they learned during skill building activities. In the posttest, more students described a method for their estimates than did in the pretest—a total of eleven students as compared to six from the pretest were able to state a reason with their estimation. Table 4.3 illustrates the range of ages and how students performed on the estimation posttest.

Generally, there were two methods of estimation. The first involved counting the number of “rows and columns,” which included counting the height of the candies seen around the outside of the container and multiplying by the size of the candies to estimate the number inside. One student who attempted this method was Terry who estimated 185 pieces of candy, by counting the height of the candy and multiplying. To obtain this number, Terry “counted around the whole outside of the container, and then the bottom of the container. She added the bottom number to the number from the sides and deduced that it was about 185” (Notes from Posttest, 8/14/02). At least 5 students used some variation of this counting method. The second method utilized two preliminary estimates to estimate pieces of candy per volume unit. For example, Anna first estimated how large the container was by comparing it to 1 cup. She “remembered” that 1 cup was equal to 16 ounces and determined that there were 6 candies per ounce. From these estimates she was able to calculate an estimate of 96
candies (posttest notes 7/13/02). Three additional students utilized a method similar to this comparison method. The students’ ability to state an estimate with a stated explanation increased significantly from pretest to posttest ($Z = -3.017, p < .003$).

**Prediction**

The fifth process skill task for students to complete was based on developing a prediction using established data sources. Prediction is a critical thinking skill that students use in a variety of subject areas. Prediction skills are important for students to learn to state what they believe will happen and why before actually seeing the results.

Students were asked to study five individual weather maps from the past five days. Individually, they were given basic verbal instructions on how to read a weather map and use a map key. The graphics and text of the five weather maps showed a storm moving progressively closer to Ohio from the west. The students’ task was to predict the weather in Ohio on the day after the fifth map, either verbally or by filling in a blank weather map (indicating cloud cover with the appropriate color from the map key). Students were expected to be able to read the information on the weather map and provide a prediction of the next day’s weather based on the provided information. There was a range of predictions in pretest results. After reading about a storm headed east toward Ohio for the past 5 days, it might seem obvious to an adult what type of weather to expect; however, nine of the students provided predictions that did not correlate with the evidence. For example, Karen stated that the weather would be
“slightly sunny, with maybe a little bit of rain if the clouds came in from the east.”

When asked to clarify her statement, she said that she had read the weather maps, but “I don’t agree with them, they don’t make sense” (pretest notes 8/13/02). The student ignored the data provided because she was sure her ideas were right, whereas the information on the map seemed incorrect to her. Five of the other students who stated predictions not based on evidence provided did not take the time to read the information stated on the task cards.

Teachers and camp counselors worked daily with students practicing scientific predictions; most were about the weather. During lunch each day, students and teachers studied the sky, wind, and clouds and predicted what the afternoon weather would be. After camp each day, they would observe the weather and discuss their predictions. The students began to watch the weather at night to compare their predictions with those of the weatherpersons.

In addition to the daily weather predictions, students participated in a group activity called “How Much Water Will A Baby’s Diaper Hold?” Students were asked to predict how much water a diaper would hold. Many students with practical experience in diaper-changing decided that the diaper wouldn’t hold more than a cup of water, and they were surprised to learn that it could hold more than 15 cups of water. We discussed the difference between water and human urine and how that knowledge, or lack thereof, affected the success of their predictions. The lesson they learned was to

11 Please see Appendix D for the verbal directions and an example of one of the weather maps that was provided for student use.
be sure that they had as many “facts” or pieces of information as possible before stating a prediction.

Throughout I Wonder camp, students were asked to make daily predictions in their logbooks about their individual inquiry projects, but these notes were not required. Most students recorded predictions for their individual projects at least three times. For example, one student, Anna, who compared three different crayfish (no claw, one claw and two claws), recorded that “the one with two claws would grow more than the others” (tape recorded 7/31/02). Unfortunately, she was unable to test her prediction, because the other crayfish died soon after her predication was made.

During the posttest, thirteen of the students demonstrated a significant increase in their ability to make verbal and written predictions from relevant information. During the pretest, nine of the students did not use evidence to make their predictions. During the posttest, only one student made a prediction without the aid of the provided information. For example, Karen who could not made a weather prediction not based on the evidence in the pretest, stated, “it will be a rainy day because the clouds over Ohio are blue and blue means rain or thunder storms.” She made an accurate, evidence-supported prediction based on the same type of information available during her pretest. This implies that the students were more cautious and took note of the provided evidence before making their prediction. The students’ ability to make accurate predictions increased significantly from pretest to posttest (Z = -3.307, p < .001).
The final task students were asked to complete involved written communication, the primary medium scientists use to express their findings. Individually, students witnessed a demonstration using “happy and sad balls.” The happy and sad balls were two balls that looked and felt the same, but responded differently in motion when bounced on a hard surface. The students were asked to describe the demonstration as if writing to their best friend on the paper provided. They were also provided with colored pencils and instructed to use drawings if they wished.

Given the range in ages, a variety of communication styles (written, drawings, verbal descriptions) were anticipated. During the pretest, nine of the students included a drawing. However, of those who completed a drawing, seven did not include any labeling or written explanation of their work. For example, Anna drew a typical wordless sketch depicting a hand dropping two balls; the balls are at the bottom of the page, one has an arrow pointing up and down beside it (it’s bouncing and “happy”), and the other one is depicted as motionless (it’s “sad”).

Five of the students who responded with writing did not describe the demonstration, only their explanation of the difference between the balls. For example, Jeff wrote:

It has a havie cardbroard in It.
It has bounce rubber (Jeff pretest 7/8/02).

One of the balls—the “happy” ball—would continue to bounce as expected, while the “sad” ball would not bounce, but stop moving when it reached the table surface.
Notice that even if readers were only interested in the difference between balls, this would not be enough information to discern between the two. The researcher asked Jeff for clarification and added notes next to each description; the first line refers to the ball that fell flat (the “sad” ball), the second to the ball that bounced (the “happy” ball).

Other students, such as Teresa, described the demonstration without contemplating why the balls bounced differently.

“The ball stop bousen and the other one kept going” (Teresa pretest 7/8/02).

When asked if she had more information to add, she replied, “I wrote down what I know.” Both Teresa and Jeff demonstrated poor grammar and communication for their respective grade levels, but were representative of the typical summer camp participant. Most students had difficulty with written expression of thoughts and ideas therefore, individual writing exercises were needed to practice descriptive sentences and written explanations. First, each student participated in an owl pellet dissection\(^\text{14}\). As part of the dissection we discussed predator/prey relationships; students found the remains of one or two animals in their dissection. They were asked to write a story in their journals that would describe the prey’s experience. As seen in pretest results, students used unlabeled drawings and short, non-descriptive sentences for their explanations; some

\(^{13}\) The examples given in this section are written as it was on pretest or posttests, including the misspellings and sentence structure. No changes have been made to his work.

\(^{14}\) Owl pellets are the regurgitated parts of prey that were not digested by an owl. Typically bones, fur and pieces of skin are regurgitated.
students did not participate at all, indicative of confusion or being introduced to a new concept. In figure 4.1 Jane’s written story is displayed. Notice that Jane attempts to add some of the science content we talked about as part of the activity instead of writing a creative story. Jane represents one of the students who has quite good written communication skills compared to the other students. Figure 4.2 displays Tabithas’ representation of her story. For her description she drew two pictures. Then the teacher—JoAnn, used dotted lines to allow Tabitha to trace over the names of the creatures she drew. Then the teacher wrote the story that Tabitha described verbally. JoAnn recorded verbatim Tabitha’s comments.

Figure 4.1: Teresa’s story about the owl.
Figure 4.2: Tabitha’s drawing and story$^{15}$.

$^{15}$ The written words from this representation were recorded by the teacher leading the activity, JoAnn.
During I Wonder skill building activities, project activities, and even other camp activities, students were often given specific questions to respond to in order to aid their understanding of the type of information that is important to record. Also, students were frequently reminded to write their conclusions in their logbooks at the end of each activity. When possible students were encouraged to create drawings or data tables to represent their findings. Each of these guided instructions added to the students’ knowledge and ability to recognize important information.

Verbal language and communication (e.g., stating scientific conclusions; describing processes, events or objects) was stressed throughout the duration of I Wonder camp in expectation that it would materialize in students’ writing. Writing was used in the majority of activities, in combination with other skill tasks such as prediction and observation. Student logbooks served as a source of writing practice, too, and scientific language was encouraged by prompting questions in the logbooks. By the end of their individual I Wonder projects, students were expected to write a research article describing their project and its results. To guide their article format, students were given a set of six questions to answer.

During the posttest task, students were expected to provide written explanations, as well as labeled drawings. In posttests, all students showed improvement in their written scientific communication skills. In pretest and I Wonder activities, students often had difficulty writing a single sentence to represent what they knew. By the posttest, all students (except one) were able to provide, at minimum, a drawing with prompted verbal explanations. The majority of students (67%) were able
to provide written explanations of the demonstration and hypotheses about the
difference between the balls. Overall, students seemed more comfortable answering
verbal questions about their ideas. This behavior could be a function of their maturity
level, comfort level with the researcher or even with the writing process itself.

Teaching grammar and sentence structure was beyond the scope of I Wonder
camp, but would have been helpful had there been more time. While poor written
grammar skills remained, many students increased the amount and type of information
they included in their writing. For example, Teresa (previously described as writing
one short sentence that simply stated what happened in the demonstration, and having
nothing verbal to add) included several sentences and elaborated verbally on her
message:

“One of the balls bounsed and one didn’t bouns. The didn’t bound is made out
of thiker ruber. The bouns one is made out of thiner ruber” (Teresa posttest 8/13/02).

The researcher noted that she continued her message verbally out of frustration with
her writing ability, as it took over 6 minutes to write the 3 sentences above: “Both
will bounce on the floor on the carpet. The table is hard, so the thicker rubber gets
stopped, I think, I don’t know” (Teresa posttest 8/13/02).

Anna, who sketched a drawing in the pretest with no written cues, added
written remarks in the posttest. As one of the “natural” writers in the group who
frequently recorded ideas in her logbook and enjoyed writing the journal article, Anna
surprisingly chose drawing to represent her understanding of the ball demonstration.
Janes’s pretest results consisted of no more than two sentences; her posttest results were as follows:

I would say, “there is to rubber balls.” I would droup the bad ball. This ball didn’t bounce but watch me bounce the other one. It bounces very well. Which means the other ball has a weak amount of rubber and maybe some plastic. But there is a lot of rubber in this ball and there is no plastic” (Jane posttest 8/14/02).

In the posttest, Jane referred to the actual writing assignment (explain the demonstration to your best friend). Only two students wrote their explanations in this fashion. Which implies that students are still having difficulty following directions.

Note in each of the posttest transcripts above, Teresa and Jane tried to identify the difference between the balls, which was something they could not see. In the posttest, most students also attempted to give a reasonable explanation for the “happy” and “sad” balls, while only three students did so in the pretest. Which may imply that students are learning to seek explanations, and perhaps, thinking more like scientists.

The students’ ability to communicate their observations and understanding using multiple representations increased significantly from pretest to posttest ($Z = -2.950$, $p < .003$).

**Conclusions**

Overall, pretest and posttest data and document analysis supports the notion that skill-building activities and practical experience in science process skills helped each student increase his/her scientific literacy during his/her 6-week I Wonder camp
experience. Students used the skills of observation, measurement, prediction and communication almost daily, due in part to the informal nature of their learning experience (e.g., predicting weather patterns at lunch). Posttest comments on the repetitive practice of these tasks, such as “we have been doing this over and over again,” indicated that this type of guidance makes students aware of their own learning process. They also became aware of the culture of science, instead of thinking of it as another school subject. For example, when students “forgot” which side of the meter stick to use for measurement, they would ask “which side is the science side again?”

Other skills tested, classification and estimation, were not practiced as frequently as the rest, but were reviewed in several group skill-building activities. Neither of these skills was the primary task of individual I Wonder Projects. However, based on posttest results, students retained and improved these process skills during the posttest.

Learning process skills was a major factor to enable students to be successful with their I Wonder Projects. The lack of students science process skills forced the researcher to reevaluate how much time and number of skill building activities that would have to come before the students could be expected to plan their own self-guided inquiry projects.
CHAPTER 5

BUILDING A SCIENTIFIC COMMUNITY: ESTABLISHING THE
INSTRUCTIONAL CONTEXT AND COMING TO KNOW THE STUDENTS

Introduction

Another major issue facing the success of the students’ individual I Wonder Projects was the initial ideas and beliefs of the children about science and scientists as well as the lack of teamwork or willingness to work together demonstrated by the students early in the process. It was important to help broaden their definition of science and the processes of science for students so that they would be able to participate successfully in the I Wonder Project. The purpose of changing the definition of science had two purposes, a.) for the students to be able to participate more fully in this project, and b.) to broaden their knowledge of school science to a science in action view of scientific science. I begin this chapter with the discussion of the entering ideas, attitudes, and beliefs of students about science to set the stage to begin to lay the groundwork for the need of building a community. The chapter ends with a description of the key elements necessary to build community with this particular group of students and the activities that were used to do so.
Students Attending Summer Camp

As described in Chapter 3, there was a wide range of ages (from 6-12) of participants in the summer camp. Originally, there were approximately twenty students attending on any given day. However, only about fifteen of those students remained throughout the six-week camp. Of the fifteen students, only four were male: Jeff, Anthony, Ken, and James. The remaining students were female: Teresa, Tina, Jen, Anna, Ariel, Karen, Anita, Tabitha, Jane, Nancy, and Terry. More than half (10/15) of the participants were African American, while the remaining students were Caucasian.

There were three different prior educational backgrounds represented by the students: rural, urban, and private religious. In addition, their socioeconomic levels ranged from affluent to poverty. Because of the range in ages, socioeconomic levels, and educational experiences, it was important to understand what each of the student had experienced with science at home, in school, and in the media. Also of interest were students’ ideas about scientists, what scientists did at work, and at home, as well as how they transmitted their knowledge to others. These ideas will be presented in the following section of this chapter.

In order to learn more about students beliefs and attitudes of science, pre interview questions were asked based on the interview questions from the Draw a Scientist Test [DAST] (Chambers, 1983). Finson, Beaver, and Cramond (1995) stated “the scoring of the DAST can be somewhat cumbersome and important stereotypical elements may be omitted during rating and scoring” (p.201). Changes have been made
to the DAST scoring that include several interview questions which determine the students ideas and perceptions verbally. For this study, these verbal questions only were utilized and imbedded within the pre-interview survey. The students were only asked to answer the interview questions so that there would not be error in adult interpretation of the students’ drawings. Interview questions are described in detail in Appendix B- Interview questions.

Students completed the pre-interview questions before beginning the I Wonder Process. The students’ responses were used to adjust and implement the I Wonder timeline, procedures, and skill building activities. Combining information about students’ remedial science process skills and the perceptions of science and scientists resulted in changes for beginning the I Wonder Projects. This will be elaborated in the second section of this chapter.

Students’ Ideas About Science

Science is used in two distinct ways by students and teachers in this project. According to Miller (1989), “many school science ‘experiments’ are paradigms; their function is to show what is involved in doing science (p. 55). However, these experiments tend to be structured and the final answers are known or quickly determined by the students to confirm or to “see” scientific concepts. Within a broader science definition these types of experiences can add to the students understanding and development of ideas. However, students also need to be engaged in investigations scientifically. “Tackling a problem scientifically is not a matter of following a set of
rules—the ‘scientific method’. . . . We learn how to investigate scientifically through amassing experience of a wide range of paradigm approaches to problems which, taken together, embody the tacit aspects of ‘working scientifically’” (p.55).

Students typically define science within the boundaries of their personal school science experience. For example, Anna defined science as “something you experiment with” (pre-interview 7/8/02), or “it’s a way to get kids to know about the world or how things work” (Anita, pre-interview 7/9/02). These definitions relate to their own school experiences with science; things that they had done with science. Even Anita referred to “the way to get kids,” meaning herself and her fellow students, within the realm of school science.

Other students had different ideas about science, more focused on the traditional definitions of science. Karen reported that science was “the study of chemicals, or the study of life” (pre interview 7/8/02). While Ken suggested that it is “the study of animals, plants, and how people live” (pre interview 7/9/02). These students each referred to the definition in regard to “the study of” instead of how they might have actually participated in science as described above. Yet, another student embedded some of the traditional ideas of science with a little of his own person learning of science, linking these two ways of thinking about science when he stated, “like when you get to know stuff about the world, like God made, and sometimes in science you can learn about gadgets and stuff like that. But, most of it is about studying plants, the weather, building, creating, the things on Earth that you normally see” (James pre interview 7/9/02). The insert of God references his private school and
possibly home beliefs about science, whereas the end of his definition includes the traditional “study of” portion of the definition.

Curiously, none of the students reported that science was fun, or interesting, but two students did refer to it as boring. Compared to other research on students’ ideas about science from the DAST research where at least some of the students refer to science as fun or interesting, these results were perplexing. When I asked the students if they enjoyed science in school, most of the students replied that they were either not good at science, or that it was boring in school. There were a few exceptions to the rule; however, the general consensus of the group was that science was not fun or interesting. If they weren’t interested in science at all, it would be problematic when they were asked to design their own science investigation.

However, science for this project needed to have a broader, more contextual meaning of science as a set of social practices including: asking questions, developing ideas, and communicating those ideas to others for constructive criticism. This type of definition was necessary to overcome the lack of curiosity of science, the ability to claim they didn’t like science based on their school science experiences, and to give students the opportunity to engage in science practices in more collaborative manner (Wells et. al., 1990).

Scientists at Work and at Home

In order to further understand students’ beliefs and perceptions about science and scientists, students were asked to describe what they thought scientists did at work and at home. Overwhelmingly, students agreed that at work, scientists did
experiments or were involved in inventions. Interestingly, Teresa commented that “scientists teach what other scientists do like activities and projects” (pre interview 7/8/02). Her reference to teaching about science was unique among this group of students.

However, there was quite a range of beliefs about what scientists do at home. For example, six of the students suggested that scientists did mostly work or other experiments at home. Three students said that scientists would have to “sleep because their job is so hard”, meaning they would be too tired to do anything else. Two students considered the work of scientists not to be over and that they would have to come home and “study” to get ready for the next day’s work. The last suggestion made by students was that the scientists would “teach their kids about science” (Jeff pre interview 7/8/02).

These ideas are not based on actual knowledge of scientists; none of the students reported actually knowing a scientist. Therefore, their ideas had to come from other sources such as school, television, or even the movies. When asked the source of these ideas, almost all of the students replied, “I don’t know”. When questioned further, they tended to repeat whatever the final possibility was, therefore, not a true reflection of where their ideas came from.

Few of the suggestions about the home lives of scientists contain an appealing view of the lives of scientists. These ideas about the lives of scientists then relate to the students responses to the question “Can you be a scientist?” as described in the
section below (“Students as scientists”). It is important to keep in mind that the I Wonder Project relies on student-developed ideas and if their ideas about science or scientists are negative, it could be difficult for them to successfully complete the project.

Scientists Share their Ideas

Another part of the I Wonder Project is that students share their ideas with the teachers and other students. However, as commonly cited in the DAST research, students often portray scientists as working alone, and rarely sharing ideas with others. I was interested to learn how students thought scientists shared their findings or ideas with others before we began the projects. Students responded to this question in three main ways. First, five students suggested some sort of written communication, from writing in their notes, to writing a paper and sharing that paper. Three students commented that scientists share their ideas by “telling other scientists after they were sure.” And finally, three students reported that they would show others the work in the lab. These ideas were consistent with the reported ways in which students had learned about science themselves except for the showing others the work in the lab. However, this could have come from any number of popular media sources.

However, unlike the multiple suggestions for sharing science ideas, when students were asked how they would share their science ideas, almost all of the students (13/15) reported writing it down. One other student suggested “let them come

16 Students were asked if they learned about science and scientists at home, at school,
to the house and do it with me so they wouldn’t be bored” (Jeff pre interview 7/8/02). Another replied, “I would video tape it because it would be better than my words” (Karen pre interview 7/8/02). These ideas of sharing their ideas were in direct contrast for the types of interactions the researcher was hoping for during the I Wonder Process. Discussions of ideas and thoughts with other peers and teachers would be important for their success.

**Students as Scientists**

When asked at the beginning of summer camp if the students believed they were scientists or could be scientists, the majority of students (11/15) reported “no”. Many of the students stated they couldn’t be scientists because they didn’t get good grades in science. Others had misperceptions about how long they would have to go to school to become a scientist. Another student reported that she didn’t “want to have a job where I could leave the office sometimes and not have to spend all my time at work” (Jane pre interview 7/9/02). These negative perceptions about the lives and work of scientists have impacted these young childrens’ ability to envision themselves as part of the scientific world.

In contrast, a few of the students who stated they could be scientists stated reasons such as, “if one person can do something, then everybody can do something” (Anna pre interview 7/8/02), while another student stated that “science is making things, and I like to make things” (Jeff pre interview 7/8/02). There was quite a range on TV or movies.
of beliefs and attitudes about the students themselves being scientists. In order to build a scientific community of learners, several steps would have to be taken to broaden the students’ ideas and perceptions of science and their ability to be scientists themselves.

**Needs of the Learners- Groundwork for Social Interaction**

These interviews about student perceptions of science and the pretest skill described in chapter 4 revealed that there was a great deal of work to do before students would feel comfortable and confident working independently. In addition, individual needs of the students also impacted the goals and timeline of the I Wonder project.

Students who have little or no experience with scientific investigation may have difficulty being successful in a self-guided environment without being introduced to the scientific culture (Lave & Wenger, 1991; Shultz, 1976). During the first several days of summer camp, it became clear that most students lacked at least some science skills (Chapter 4) and proper motivation (prior experience). Compounding these problems, most students were not at camp out of personal interest, but as a result of parental guidance. For example, one parent brought her two daughters to maintain their academic proficiency (in an informal, fun environment) because she was concerned they would lose their skills over the course of the summer:

Right. Just to keep the academics going through the course of the summer. Some parents when they send their kids out to camp sometimes they don’t reinforce academics through the course of the summer, so by the time kids get back in to school, they’re at least six weeks behind academically because they haven’t had that practice of skills reinforced during the course of the summer.
So I thought this would be an opportunity to allow them to keep their skills motivated. (Interview with Linda, 8/7/02)

Other parents had social goals for their children. For example, Terry’s mother wanted her to have consistent social companions to help develop her social interaction skills, which her teacher had noted were developmentally delayed during the prior school year (Interview with Sue, 8/8/02).

In order to meet the expectations of parents and researchers, a scientific community where students could use their skills and broaden ideas about science need to be developed and nurtured in a short period of time so students were comfortable sharing their ideas. Skill-building activities, while serving as a foundation of practical science skills, allowed students to communicate in a number of group sizes and one-on-one, building confidence and motivation with their scientific ideas.

Goals for the Scientific Community

Building a scientific community of learners is an on-going process, however there needs to be at least some common ground for the students to feel comfortable participating. Though the camp was concerned with cultivating a community in which students took control of much of their own learning, the camp teachers nonetheless had particular learning objectives and they developed activities for the students to participate in to obtain these objectives. Several specific teacher/counselor concerns were addressed among researchers and camp staff at the beginning of camp to build the I Wonder science community. Five primary areas of improvement were identified:
1) Sharing ideas;
2) Valuing individual and group participation;
3) Learning to develop and ask questions;
4) Determining a common language about science and scientific processes;
5) Agreeing upon a set of rules.

Because building a scientific community of learners is an ongoing process, these areas of improvement were addressed daily by students, teachers, and counselors.

Embedded into every activity were conversations about “how scientists would handle a similar situation” or how the students could behave “as scientists.”

Activities along the inquiry continuum (Chapter 2) is important for students to develop the goal of “science as process.” In order to do this, the students needed to develop common expertise in inquiry and scientific process skill methods. Donovan, et. al. (1999) suggest that people need three common characteristics:

1. a deep foundation of factual knowledge,
2. understand facts and ideas in the context of a conceptual framework and,
3. organize knowledge in ways that allow for retrieval and application (p.12).

These characteristics are also important for elementary students who are participating in an open-engagement of science. First, in order for students to be able to accurately explain predictions and explanations; second, students need to understand the difference between school science and the work of scientists in a real context; and finally, students need to be able to participate as scientists, which includes communicating ideas verbally, and in written format in their science logbooks, as scientists might.
In addition to the comparisons to scientists, students need to learn to work together in a positive manner. Johnson and Johnson (1975) suggested that students need to work together to solve difficult problems, but also alone to complete individual tasks. For some children understanding when to ask for help and when to work individually can be problematic. Much of this difficulty is understanding the social and cultural context the students are working under. For many of these children, science is an independent endeavor where science is reading from a book, but not exploring. For other children, science was a cooperative event, where the teacher told them what to do and they completed the task in groups. To ask students to work in groups on skill building activities and then work independently on their own inquiry project is to set-up a context in which the students have no experience participating (Lave & Wenger, 1991).

To learn in the new social context, students need to overcome the crisis of not knowing (Shultz, 1976). They need to learn to adapt to the new social rules and either choose to participate within the new rules or refuse to participate. The job of the teacher in this setting was to minimize the “crisis” as much as possible by slowly introducing student to the new rules of science and to independent self-guided work. Developing a new community with clear rules that students can follow and participate with aids this goal. Rogoff (1990) and Lave and Wenger (1991) suggest an apprenticeship model for aiding students in this transition. Most of these students had little or no experience with self-guided science participation and therefore, were going
to need more time and practice before being ready for real apprenticeship towards being actual scientists. However, with the primary goals students could move closer to behavior like actual scientists during self-guided inquiry projects.

In order to build a community where students can act as scientists by constructing a collaborative community the teacher needs to take a role as a facilitator. To do so Wells, Chang, & Maher (1990) suggest two ways to do this: a.) the teacher should not assume expertise and authority about the work, and b.) a more informal conversation between teacher and children. These two strategies will allow students to feel more comfortable pursuing topics of challenge and interest to themselves (Wells et. al., 1990). In doing so, students may be more willing to put effort into the self-guided inquiry projects.

**Building the “Scientific Community”**

Building the scientific community required imbedding student ideas and skills into activities while challenging the students to meet the five primary goals of the community. Each of the goals (sharing ideas, valuing individual and group participation, developing questions, using similar scientific processes, and following social rules) will be discussed in detail in this section.

*Sharing ideas* in a positive manner is central to the transmission of scientific ideas and methods. During the first week of camp activities, students would often say that another student’s idea was “stupid” or “you’re not making sense.” Students seemed interested in the “right” way to proceed, which they assumed only the teacher
knew. These types of communication did not promote an inquiry approach to science or a community of learners.

To combat these attitudes, we taught students to work together as peers and scientists. For example, “Lost on the Moon” was an activity that students had to accomplish as a team (to make it safely back to the mother ship after crash-landing on the moon). Another activity asked students to work together in pairs and create a model of the ACME Volume Exchanger, proving that scientists can’t “make water.” This activity required students to listen to initial information given by the teacher and to defend their individual and team ideas. During this activity, it was particularly evident that students were beginning to respect one another’s ideas. This can be seen in the following transcript where two students are comparing ideas about the ACME Volume Exchanger before they draw their ideas on the paper.

T-But, here’s my question for you, “how did she get water in there?”
Karen-Easy, she just poured it down there.
Jen-But, when she poured it down there, it comes out.
T-But, it comes out, so she only poured in 400 milliliters, how did we get, what 400 milliliters six times?
Jen-Because all this water’s in here and she poured more.
Karen-“How did that water get in there?”
Jen-She put it in there!
Karen-When?! She couldn’t have. She can’t unlock it. If she pours it in, it comes out!
Jen- it was in a tube, the water was in the tube.
Karen-What tube?! The funnel? . . .

17 Described in Chapter 3: Methods
Jen—You’re not listening. You’re not listening to me.
Karen—How did the water get to that tank?
Jen—She poured it in there.
Karen—Okay, try to explain it.
Jen—There is the funnel, and you poured the water through the funnel, and then there’s a cover protecting the other water that was in there, and then when the water comes down and hits the shell, that bounces off and goes through the funnel and comes out, “what do you think?” (Tape recorded 7/26/02).

Notice that the Jen reminded Karen she was not listening and then Karen allowed Jen time to explain what she was thinking. Jen then had time to elaborate on her thinking. In addition, Jen ended by asking Karen then to take a turn and explain what she thought.

Second, students learned how to value both individual and group participation, using one to develop the other. Once students realized they would eventually be working independently on their I Wonder projects, they began to worry that “my ideas aren’t good enough” (Terry 7/15/02). However, when placed with one or more other students with similar goals in skill-building activities, students felt more comfortable with their individual work. For example, students were placed in groups of three and asked to share resources among their group members. Individually, each student had to build a different insect using directions and resources such as apples, carrots, and chocolate candy. During this activity there was individual accountability but low pressure to have all of the answers. Initially, there was some disagreement about how to share the resources, but once the students realized there was enough for everyone they began to share.

Many students had a difficult time developing a question or questions based on observations, indicating they had little experience with the type of critical thinking
and reasoning required for open inquiry. For example, students were given the
opportunity to plant flower bulbs in different experimental situations, but students had
difficulty producing experimental situations from questions. It was only after a great
deal of guidance from counselors that the students, as a group, were able to decide on
light/dark, and water/no water experiments. Further activities were structured so that
students had to pose questions to continue with the activity. For example, students
were shown a flashing ball and asked, “What do you want to know about this object?”
A list of questions was created; in pairs, students attempted to answer, “What’s
inside?” Asking questions as part of a larger group gave students insight into multiple
points of view and helped to build individual questioning skills.

*Developing similar scientific processes,* such as data collection, measurement,
recording, and discussion was primarily accomplished through a series of experiences
called “scientists’ meetings.” Scientists’ meetings produced a structured, formal
environment that helped students’ focus on skill-building activities and how to relate
these activities to their individual projects. Each student presented his/her ongoing
research results as part of these meetings.

One skill-building activity involved determining the type of information that is
important for scientists to record. This activity was developed when it was determined
that students used their own logbooks to record questions/ideas when prompted by the
counselors, but they were not recording other pertinent information: “There is a need
to reemphasize the importance of recording information in student logbooks, activity
needs to be determined so that students develop a better idea of why scientists would
record information” (Researcher’s field notes, 7/24/02). The activity was more than simply listing items used in an experiment. Instead, the focus was to help students understand what was important enough in the scientific activity to note in their logs.

The following discussion took place after students completed the activity:

T- Anna, what’s your idea about what scientists need to record in their books? What kind of stuff do they need to put in that?
Anna- I don’t understand.
T- In their notebooks, what do they need to record into their notebooks?
Anna- Chemicals that they used.
T- Good, materials they used like chemicals. What’s yours, Jeff?
Jeff- How to build a building and report to the others.
T- So you think they would write down their plan?
Jeff- Yes, and buildings.
T- Ok. Good. What do you think is important, Ken?
Kenn- Projects they are doing.
T- Are they gonna write down what it takes to do the projects? So do you think that should be something that you write down also?
Kenn- Probably. (Tape recorded 7/12/02).

Note the instructor defined student answers in scientific language so they were applicable to any experiment; the teacher said “materials they used” when referring to chemicals and “write down their plan” when referring to construction plans.

Finally, teachers communicated that even though I Wonder was summer camp, some of the rules for school and groups still applied to create a safe learning environment. Rooms allotted for summer camp were in three different buildings, so there was frequent shifting from space to space; students usually needed a reminder to pay attention in the new space, as is common in formal school after recess or lunch breaks. Students also developed safety rules during other camp activities and applied them to I Wonder.
Conclusion

To begin the scientific community was almost non-existent but over time the students began to follow the five primary goals. It was important to build a scientific community of learners because many of the students had a negative opinion about science and the work of scientists. In addition, many of the students met for the first time at camp and needed to learn how to work with other strangers. Five primary goals for building a community of scientific learners were addressed by camp activities and described here: (a) sharing ideas, (b) value of individual and group participation, (c) learning to develop and ask questions, (d) a common language about science and scientific methods, and (e) developing an agreed upon set of social rules.

Building a scientific community aided the students in having a better understanding of how to ask questions, share ideas, and design scientific investigations more like actual scientists do. In addition, building the community aided the group in being able to work together and share ideas constructively, instead of destructively. However, these activities alone were not responsible for bringing all of the students on board at the same time, as will be elaborated in Chapter 6 to follow.
CHAPTER 6
PRIOR KNOWLEDGE SHAPED THE PATH TO LEARNING DURING I WONDER

Children came to summer camp with their own social history. Some of the students quickly adapted to the group, while others were content to “work alone”. But what was consistent for each student was the accomplishment of searching for the answers to their own personal I Wonder questions. Each students’ prior experiences at home, at school, in the world, and even at summer camp greatly impacted both positively and negatively the students’ discovery process.

The aim of this chapter is to describe the journeys taken by some of the students as they completed their self-guided inquiry projects. Their unique paths—some with the guidance of the teacher and others mainly on his/her own (as described in Chapter 7) all lead to completion of a self-guided project. What became clear to the camp counselors and myself during the six-week interactions with the students was how important meeting the individual needs of each child was in the success of their individual participation. Each child worked on his/her inquiry project differently—some with great enthusiasm, others with almost no curiosity for the end result. However, the results were often the same—“I didn’t know that…”
I was continually struck by the difficulty the children had in asking a question, let alone multiple questions. When the students had the opportunity to ask any question, even those who were interested in science felt at a loss to put into words what they were interested in learning more about. Normally, young children are filled with questions about the world and how it works. It was slightly unnerving to realize that many of the children at summer camp were already into a “just tell me the answer and let me memorize it” frame of mind. Their unwillingness to think deeply or challenge themselves is an important issue on which to focus. As this chapter will show, many of the students did not have prior experiences in asking scientific questions at home or at school and this impacted their ability to do so at summer camp. In this chapter I will argue that students got their ideas for their I Wonder Projects from a variety of sources, but prior experiences all played an important role in the interest and completion of the projects. I will show how these prior experiences impacted students ability to do science by describing in brief detail the students reported home life, school science experiences, where their project idea came from, why they reported interest in the project, and how they proceeded with their project. Allowing students to use their prior experiences to choose any science topic to study that they wished was a unique opportunity for most students and their engagement in the activity is of interest to elaborate.
Jeff: “I didn’t know that brittle was the science name for crunchy”

Jeff was an eight-year-old African American boy in the third grade. He came to camp everyday, although rarely willingly. Each morning at the drop off location, Jeff would refuse to get out of the car, run back to the car to give his mother another hug, or just generally drag his feet while walking to join the group (researcher field notes 7/22/02). Jeff was clearly stressed by being separated from his mother and although never actually explicitly stated, I assume much of this behavior was due to the fact that his mother was pregnant and having some minor difficulties with the pregnancy.

Jeff became very interested in studying mold after reading an article in the 1995 I Wonder Journal about a study of growing mold. This article included the study of the effect of different substances on the growth of mold on bread. Jeff decided to build on the previous I Wonder Journal article and study the effect of different substances on the growth of mold not only on bread (wheat and rye), but also graham crackers and cheese. Another student (Teresa, described next) was also interested in studying mold and in the beginning it was a real problem for both students as they felt the other was copying. With a little adult intervention, both students got their mold growing underway, both with similar base substances, but with different additives.

Jeff’s personal experiences from home and school seemed to greatly impact his participation in summer camp. For example, Jeff initially was unable to come up with even one question he was interested in studying as was noted by the lack of questions listed in his student journal. Part of the problem was he (like other students in the
Jeff was only going into the third grade at the time of I Wonder camp, however, it seemed that already he was not curious about the world or how things worked. He was constantly asking the camp counselors to “tell” him the answers, or to “show” him how to do something. Usually, in young children there is still a natural curiosity to figure out how things work or why things are the way they are. It was rare to hear a question from Jeff at any point during the camp. However, he did become very interested in the mold project and couldn’t wait to see the continued growth each time we met for I Wonder.

Jeff was very active in recording and drawing pictures (See Figure 6.1) of his mold and has shared his observations well with the small group working nearby. He was often very excited when something new had occurred and I am sure was sorely disappointed when it got too smelly for the others to tolerate his experiment further. He stated that he had shared his questions and researches with others at home especially his grandmother and friends from the neighborhood (midterm interview tape recorded 7/27/02). He seemed very proud of what he had learned while completing his projects.

When asked what he learned from completing his project he said I learned “the science name for crunchy was brittle” (post interview 8/14/02). Not only did he remember the term, but also he used it several times in his data charts, as well as in verbal descriptions to peers and teachers. After asking Jeff what he thought about science after completion of his project he replied, “it is kinda learning and not
learning. I mean science is fun, not being away from my mom, but I didn’t know that it could be fun and learning together” (Jeff final interview 8/15/02). He seemed to not only have learned new science information, types of things that mold grows on, but also scientific ways to explain what he learned. Imbedded in the new knowledge is also a change in attitude about what science looks like and is about—fun and learning—which is important to keep in mind.

Figure 6.1: Jeff’s representation of his mold data on day 6.
In addition to changes at summer camp, his interests in science at home also changed. During an interview with his mother at the end of summer camp, she said, “I don’t know what Jeff has been learning here, but he has started a science project in my refrigerator” (researcher field notes, 8/8/02). When I asked for clarification, she replied, “he won’t let me throw away the old leftovers, he wants to know what will grow on them”. I tried to explain that Jeff was studying mold growth as part of his I Wonder Project. She said, “Where would he get an idea like that, not from me I’m sure” (researcher field notes, 8/8/02). This conversation further emphasized the lack of science questioning going on at home, but also showed the impact of participation in self-guided inquiry outside of summer camp.

These experiences and changes are important for elementary teachers to consider. The lack of participation in science investigations left Jeff with impoverished science process skills and also little curiosity about science. However, with the opportunity to investigate a science topic of interest to him and the on-going hands-on investigations with others he began to be more inquisitive and interested in science. In addition, his science process skills improved, as did his interest in science outside of the formal structure of camp or school. Jeff and Teresa are a good comparison, in that even though Jeff and Teresa pursued a similar science topic, there were many differences in their backgrounds, and as a result, their “path” in the I Wonder Process
Teresa: “I didn’t think I had a good enough idea, but now I know I do”

Teresa is a Caucasian eight-year-old female participant and worked closely with Jeff throughout the I Wonder process. Teresa has some hearing disabilities that required her to wear special hearing aides, and she normally used a microphone and headset during the school year. Her mother was hoping that at summer camp she would be able to just use her hearing aides so that “she might have a better opportunity to make friends and fit in” (parent interview with Sue, 8/7/02). Towards the beginning of summer camp, Teresa’s mother would be waiting for her to arrive right after camp and ask the camp counselors how the day went and how Teresa got along with the other students. This never seemed to be a problem because Teresa came to camp interested and willing to participate. She was eager to dive into the days’ activity and would often be the first one to ask, “what are we going to do today?” (Researcher field notes 8/7/02).

Teresa memories of school were positive. She reported reading to be one of her favorite things to do except “science or something like that” (Teresa pre interview 7/8/02). When asked what she did at school she replied, “We learn. When we were in school on Mondays, I think every Monday, there would be like a little class that we’d talk about how to speak a different language, I think it was Spanish “ (Teresa pre interview 7/8/02). It was apparent during summer camp that this experience was important to Teresa because she was heard on several occasions teaching other camp participants how to say certain words in Spanish (JoAnn interview 8/22/02). Teresa
couldn’t describe why she was part of the Monday class that seemed to be different from regular classroom instruction. I questioned her mother because it seemed like Teresa was describing participation in a gifted education program. Her mother stated “Teresa had participated in some extra programming to help children who were having difficulty socializing at school. The program was developed to help some of the school children have something in common to help them learn to make friends” (Parent Interview with Sue 8/8/02).

There were several students at summer camp who knew each other through school or families, but Teresa was a true outsider. Instead of allowing this to hinder her pursuit of friendships, she was usually the first to reach out and befriend others. Teresa was one of the few students who could easily be asked to work with anyone and she would. However, her feelings were easily hurt when someone was nice to her one day and not nice to her another day. She was kind to everyone and would often be found giving someone, even her “teachers,” a hug.

Teresa and Jeff both worked on similar studies involving the growth of mold, however, they approached the study with different (and similar) thinking and attitudes. Much like Jeff, Teresa was excited to see the daily and weekly changes taking place with her project. However, unlike Jeff this was not her only source of curiosity. Teresa was very interested in many of the projects going on around the room and would often be found asking other students what they were learning and sharing her “smelly data” with them. Also, unlike Jeff, Teresa was capable of making decisions and changes to her project without counselor intervention. However, when she would
notice that Jeff was getting individual attention, she would request help that she probably really didn’t need. For example, on one of Jeff’s “bad days” he was having difficulty focusing and one of the counselors was giving him a lot of one-on-one structured attention, Teresa kept requesting additional help as well. Instead of being able to record in her notebook as she had done in the past, (See Figure 6.2) she began to ask the counselor to do it for her. I didn’t understand why she was making this request, so I went over to question her. She replied that she “just wanted another opinion”. (Researcher field notes 7/31/02). Teresa could work by herself, but she preferred to work in a group or paired situation.
Teresa liked to work in a group setting. When asked what size group is good for science, she replied “not by yourself—too many jobs to write down. You would have help if you had someone working with you. A large group is too many, people
will fight” (midterm interview 7/27/02). Teresa worked well in groups probably because as she said in her own words, “I do what other people tell me to do” (midterm interview 7/27/02). When she was asked by adults to complete any task, she did so without hesitation. Accordingly, she would often do exactly what other students asked her to do if she felt it was “the right thing to do”. The following example highlights this argument.

Last night many of the locusts hatched and the students were out collecting shells and they came across an actual locust. This is unusual, typically locust after metamorphosis fly away and are not found lying on the ground. This particular locust was missing a wing and was not able to fly. Some of the children were observing the locust and after a short time, brought it to the attention of the camp facilitators. After making some observations and learning more about the locust the students were asked to leave it in its habitat, alone. Some of the children asked Teresa to go and retrieve it so they could play with it longer. (She was the only one brave enough to pick it up!) However, because Teresa had been told it was harmful and wrong to disturb it she was reluctant to go over and disrupt it. This led to her being shunned from the group on that particular occasion. (Researcher field notes 7/29/02).

Teresa never truly joined a social group at summer camp. It seemed as if she was always playing with different students depending on who was willing to play with her. Often her best social interactions were one on one with other children.

Teresa at first refused to participate in a self-guided study. The students were given the option of participation. It was only after the second day of working independently with a camp counselor while others were doing their projects that Teresa came to me with the request to join the group. When I asked her why she changed her mind she replied, “I didn’t think I had a good enough idea, but now I know I do” (researcher field notes). She and Jeff needed to “sit down and talk” to
come to agreement that both of them could study mold. But after they reached this agreement, they began to work well together.

In her final article about her project she wrote:

Why does mold grow? I just want to know. I had a question for my dad, what does mold grow on. I knew that mold could grow on houses. My mom told me that. So I wanted to know where else mold could grow (Growing Mold Camp I Wonder Journal, Teresa).

When I asked her to expand on this during her final presentation, she replied that she had seen mold growing on a wall of a house where her mother was cleaning. She went on to describe what a difficult time her mother had trying to get it off the wall. This personal prior experience impacted Teresa’s belief that her idea was valid and important enough to study. Without this prior experience, Teresa’s knowledge and comfort level with mold might have been entirely different and produced different results.

When asked what she learned from this project, she responded by explaining all the different kinds and colors of mold. She also remembered that it was at least seven days before she was able to see anything grow.

“Mold can be white, fuzzy white, green, green with gray and sometimes mold can be hairy. After the mold started to grow it got bigger everyday” (tape recorded 8/16/02).

She was also interested in doing a project like this again. But as she herself pointed out changes would need to be made—

“If I did this again I would change the food in it. I would put pop tarts, still have the rye bread and wheat bread, and I would have chips like Jeff did. I
wouldn’t use vinegar again because it didn’t work. But I might use a pop of some kind” (tape recorded 8/16/02).

Unlike her partner she seemed to have gained some new knowledge about mold and understood that to learn more she would have to continue her research with different kinds of foods or substances.

Teresa is an interesting student to examine more closely. Her abilities allowed her to work independently, however, she still requested aid, usually to be included. Sometimes, students need confirmation that they are on the right track and often this was the case with Teresa. Her willingness to talk about her findings and compare them with Jeff’s also made her an interesting case, because of the differences in style and approach by the Jeff and Teresa. Both of these students were young, but the youngest student can also teach us about what can be accomplished even when students are unable to write about their individual learning.

Tabitha: “I didn’t know that seeds for new flowers came from inside other flowers”

Tabitha was a five-year-old African American female going into first grade this school year. She was younger than what was stated in the original camp guidelines, but in order for her older brother and sister to participate she needed to come as well. It turned out that she was often one of the most perceptive children in the group. Her example here is interesting because unlike Jeff, she was curious about everything. Tabitha was constantly asking questions, which may be due to her age and/or non-traditional science experiences at school thus far. She was one of the few
children who did not have difficulty creating a list of ten questions. She wanted to know things like:

- How do angels survive in heaven without food or water?
- How do owls know where to build their nests?
- Why do snails eat blueberries?
- How do flowers grow? (Tabitha’s logbook).

Her questions all seemed to stem from other activities that she was recently involved in. For example, before she had the opportunity to list her questions, she observed land snails as one of the living organisms in the main summer camp room, we dissected owl pellets and talked about predator/prey relationships, and the very day we listed questions for the first time there was a discussion about heaven on the playground between a group of students. What I found fascinating was her ability to remember and apply these prior experiences to the task at hand.

Tabitha decided with some encouragement from the staff to investigate her flower question because it was one we felt she could manage successfully. Tabitha ended up dissecting over 10 different types of flowers. She would count the number of petals and open up the stem and the ovaries of each of the flowers. One of the camp counselors, JoAnn, worked with Tabitha during the first dissection and helped Tabitha figure out what each of the different parts of the flower was. She drew a picture and colored it for many of the different flowers she dissected (See Figure 6.3). She also recorded the number of petals she removed from each of the flowers. She was so excited to get to the classroom where her project was to see what new flower had arrived for her that day. She always wanted to keep the petals to take home to her mother.
Figure 6.3: Tabitha’s representation of a flower before and after dissection.

JoAnn was surprised when Tabitha pointed to the open stem and said there is the poisonous milk. At the time, JoAnn didn’t think much of the statement, but when Tabitha continually referred to the liquid in the stem as poisonous milk she began to
become concerned. I talked with Tabitha during one of these dissections to see if I could figure out where this idea came from.

Tabitha and I were opening the stem of the flower and she pointed to the liquid in the center and said that’s the poisonous milk. When I asked her how she knew this she responded, “my teacher told me”. I was then very confused so I said one of your teachers here at summer camp. She replied no the playground teacher Mrs. B at school told us not to touch the flowers on the playground because they had poisonous milk inside (Researcher field notes, 7/31/02).

This prior experience set the stage for Tabitha of what she was going to see when she looked inside every flower, not just those on the playground. It was difficult to change Tabitha’s firmly held misconception. It wasn’t until she started planting some of the seeds from the sunflower that she had dissected and they began to grow that she began to believe that there was no poisonous milk in the stems of those flowers. For Tabitha, the fact that seeds could grow meant that there couldn’t be poison inside. But she was very excited because now she knew that the seeds for new flowers came from inside the old flowers. At one point she said to me while walking back to the main classroom that she had always thought that seeds came from inside packages (Researcher field notes 8/7/02).

This case is important because it shows how important giving accurate information to children is. Teachers, parents, or any authority figure in a child’s life can greatly impact what they believe about the world around them. Once a child has formed an idea about how something works, it is difficult to change or even sometimes even to modify these ideas. Tabitha also gives an example of how early this type of scientific investigation can begin.
Anthony: “I didn’t know that bigger magnets weren’t always the strongest magnets”

Anthony was a nine-year-old white boy in the fourth grade. Anthony is an interested student to consider more closely because he represents the student with the most on or above grade-level appropriate skills. He came to camp almost everyday, but did miss on a few occasions when his mother was unable to bring him to camp. Anthony’s family lived in a nice neighborhood with a good school system. Anthony was interested in science, but not to the extent that his mother and father believed him to be. He was a typical fourth-grader, interested in something for a little while and then wanted to move on to something more exciting. The unique characteristic Anthony brought to the summer camp group was his lack of knowledge of pop culture appropriate for a fourth-grade student. When I asked Anthony if he ever watched science shows on television he replied, “no, I am not allowed to watch television at home” (pre-interview 7/9/02). This brought an interesting frame of reference to the group dynamic as far as social conversation, but also life experience. When I asked him what types of science things do you talk about with your family or friends he replied:

“Yes. When I was in third grade, me and a friend used to pretend that we were geologists and we went out at recess and work and dig. I found this one rock, and I was diggin’ at it, and diggin’ at it, tryin’ to get it out, I dug at it for like weeks and then finally I pulled it out and it was half of a cement block from the ground” (pre-interview 7/9/02).
Anthony has been actively involved in science fair projects for two years at his school. He had strong science process skills at the beginning of camp but still managed to improve in many of the skill areas even further by the end. He worked well independently, and not so well with a partner or group during group activities, mainly because he was lacking in some social skills maybe as a result of his lack of pop culture understanding. In addition, he did not like to share materials or allow others to suggest methods, which he did not agree with which did not make him popular with the other students. It was often difficult to find a partner to work with Anthony. Only the strong older girls who weren’t afraid to request equal time were successful with him. As time went on, instead of learning how to work within a pair or group, he would just allow his partner to try the experiment and then he would do it again on his own. He didn’t try to argue with others about what was the “right” answer; he just wouldn’t believe any answer other than the one that he had found.

Anthony was interested in learning more about magnets because he had enjoyed playing with them and was curious about how they worked. Anthony learned a great deal about magnets as seen by the following section taken from his final I Wonder Project Report:

I found that big magnets aren’t always better, which proves bigger the better is not always true. I found this out by using a really big bar magnet that I thought would pick up a ton of paper clips, but it only picked up one or two. Sometimes small magnets can be really powerful. I found this out by using a small circular magnet. I thought that the magnet really wouldn’t pick up much, but it turns out that it was the third best magnet. The best magnet was a small bar magnet. It was able to suck the paper clip from two inches away along a piece of paper. I also ran a test with the bingo wand. I was able to find that the longer and slower you pull it out the more chips it would pick up. (Anthony I Wonder Journal article, Magnets).
As Anthony himself explained above he tried several different tests to try to determine what was a fair test, and which magnet was actually the strongest. Anthony was able to work independently on his project. At one point I didn’t feel that he was really being challenged enough so I suggested several additional tests he might perform as well as two trade books on magnets for him to read for further information.

Anthony was fairly active in recording the information in his science notebook (See Figure 6.4) compared to Jeff who wrote little unless prompted. Notice that he even included evaluating the effectiveness of each of the magnets in his logbook: good or bad. However, he was not active in sharing any of these ideas with others at his table or even with the adults in the room unless directly asked a question, unlike Teresa and Jeff who both enjoyed sharing their findings with others. His prior experiences with science projects and manipulation allowed him the flexibility to work alone without teacher or peer intervention. Unfortunately, he was unable or unwilling to translate his knowledge in a way that would have been meaningful and helpful for the group as a whole, as Teresa was able to do with Jeff.

The example of Anthony is important because sometimes students who work well independently are allowed to continue to work alone. Anthony needed to learn social skills, how to share materials, ideas, and even help others. He had great difficulty transitioning from individual work to group work and needed more guidance in the group situations. These needs might not have been noticed in a regular
classroom where teachers are busy trying to make sure everyone is on task. But, they are still important. Without teacher intervention in this case, Anthony never would have challenged himself further, and might not have continued to explore in more meaningful ways.
Figure 6.4: Anthony’s representation of his data collection about different types of magnets.
Ariel: “I didn’t know that building a piano could be so hard”

Ariel was a nine-year-old African American girl going into the fifth grade. Ariel was the same age as Anthony and expressed some like of science much like Anthony, however, when it came to participation in scientific investigations Ariel’s approach was much different than Anthony’s. In addition, Ariel and Anthony had differing experiences in school science and at home before coming to summer camp. Ariel was not typically interested in much of the science activities planned. However, she did find herself drawn into many of the activities that involved building or creating a model.

She described her school experience as boring. She claimed that most of what she did in school was read the book and answer questions. She did comment that she had a really cool science teacher who had a rattlesnake rattler on her key chain. When I asked her to describe her science class she said:

We didn’t do much science. When we did it was mostly reading out of our old books in the classroom. Sometimes the teacher would show us stuff, but she didn’t trust us to touch the stuff, like equipment, like you do here. I knew I could do it without breaking it, but she (her teacher) didn’t think so (mid term interview 7/8/ 02).

Ariel was able to share well, but if given the option would allow her partner or partners do all of the work. When asked for her thoughts about an experiment the whole group was working on she would typically reply, “I don’t know”, unless she was certain of her response. Ariel was somewhat interested in what others were doing and when she became frustrated with her own project she would go to find out what others were doing.
Ariel became interested in her own project idea by reading in one of the former I Wonder Journals. She found an article about making a piano and this became her project as well. In the following piece from her article she explains why she was interested in this project:

My original question was how to make a piano. I chose this question because I thought it would be fun. I thought it might be fun because I didn’t know how pianos could make their sounds. I didn’t know how to make a piano and I thought it might be interesting to try. We looked on the Internet for information about building the piano but couldn’t find any information so I had to try to figure it out myself (Ariel I Wonder Journal article 8/14/02).

However, the adults and Ariel quickly learned how much of a challenge this project really was going to be. Ariel in the beginning wanted someone just to tell her how to build the piano, or actually to do it for her. But from my interactions with her and her pretest science process skills scores I thought she might be up for the challenge, at least at the beginning on her own. Ariel gave me a list of materials she thought she might need and I brought these back to camp for her.

When Ariel was sure there was no simple way to find directions, she began to brainstorm other ways of figuring out how to build a piano. She remembered looking inside a piano at school and thought that maybe if she had a model it would be helpful. The search for a toy piano began. As it turns out toy pianos only exist in the electric form. Ariel became an expert in circuits and resistors in order to learn how to put the toy piano back together again (See Figure 6.5). However, this did not help her build a piano. Perhaps because she had little experience with trial and error experimentation that this particular task was more difficult than it needed to be. Although after giving Ariel a little bit time to work on it alone, she no longer was willing to listen to
suggestions when they were offered, “I want to figure this out myself”. Maybe given more time and additional resources she would have been able to.

Figure 6.5: Ariel’s logbook entry about the electronic piano.

Ariel’s case is important because she was a reluctant starter, but once she was able to work on a project of her choosing, she developed a new appreciation for science. Even when she was struggling to build the piano, without much success, she insisted on continuing with her “trial-and-error” methodology she showed curiosity and interest she had not shown in other more traditional activities. Engaging Ariel in a project of her interest lead her to participate more, be more productive, and learn about electricity even when that was not her original intent.
Karen: “Just because some things take time to grow doesn’t mean it won’t eventually grow”

Karen was a twelve-year-old African American girl in the sixth grade. As the oldest camp participant her interactions with the program were of interest. She came to camp daily with the knowledge that she had to be there to allow her mother to go to work. This did not add to Karen’s level of interest or motivation to be at the summer camp sessions. Karen was the oldest student so by default was also a role model for the younger students. The camp counselors and myself had to work intensively with Karen on her peer interactions in order to make sure she was setting a positive example for the other students who looked up to her.

Karen struggled from the first day with any activity she didn’t or couldn’t immediately figure out the answer to. Part of the problem may have been the wide range of ages and she felt like she should know the answers. But whenever she did have difficulty the activity was quickly labeled “dumb” or “boring.” We made a conscious effort to keep the activities interesting and challenging for all of the students, sometimes even asking Karen to participate in a different way to keep her interested. However, the end results of these attempts were usually met with Karen’s resistance. For example, during the ACME Volume Exchanger activity Karen was challenged to write several sentences explaining what she thought was happening in addition to just creating a drawn model.

Today I attempted to challenge Karen a little more than the other students to keep her interested. I didn’t know if the activity would keep her interest or challenge her as much as some of the other students. When I asked her to write a short summary of her ideas she refused and said she wouldn’t do
something that others didn’t have to do. Too late I realized that she was having a difficult time conceptualizing what was inside the box. The drawing in front of her had actually been her partners’ idea and she had just agreed with him. It turned out the activity was challenging enough, and as usual with Karen, when things get tough, she stops working (Researcher field notes, 7/26/02).

This example highlights some of the difficulties getting Karen to participate in-group activities.

Karen had several I Wonder Project ideas. However, many of the ideas were things I knew she already was sure of the answer or they were going to be nearly impossible to complete. For example, the first questions Karen came up with were questions that would be difficult or impossible to answer. The following transcript highlights just a few of her questions in a conversation with the researcher about what she might be interested in studying.

Karen- Ok, how come we can’t see an atom?
T- Well, don’t you know the answer to that question?
T- So, is the question you just asked me, is your question, “why can’t I see what’s in between here and the carpet?” or is your question, “what is in between here and the carpet?”
Karen- Kind of both. Why can I see it, but it’s nothing?
T- But, it’s not nothing.
Karen- How can I see it when it’s not a color? Like how can you see the wind? How can you see rain?
T- You know that.
Karen- What color is rain? Why can you see the wind? I don’t know.
T- Yes you do. What do you look at around you, what indicates to you that there’s wind?
Karen- Because there’s air and stuff.
T- Did you really see the wind? Or do you see things that tell you there’s wind?
Karen- That brings me to another creepy question I had. What’s below us? (Tape recorded 7/18/02).
From this short section of the conversation, it is evident that Karen was not interested in taking this project seriously, nor did she want to challenge herself, but she was willing to see how far she could challenge me.

Finally, after long debates, Karen decided that she would try the controlled comparison of seed growth in different solutions of salt water. However, from her article write up, it was clear she was not particularly happy about this concession:

My first question was how the amount of salt water would effect the growth of seeds. Truthfully I originally wanted to study atoms and the human body. But unforchantly, my lab (science) teacher thought that was too easy and gave me this project (Karen’s I Wonder article 8/14/02).

Karen used carrot and radish seeds because they grow rapidly, with plastic baggies, and different salt solutions. At first she wouldn’t show her disappointment when the seeds did not grow over the first three days. But by the end of the week, she was growing anxious that her project wouldn’t be successful. After the weekend break, we returned to find growth and Karen was extremely animated as she tried to measure the growth of each of the seeds (See Figure 6.6). Then she ran into her first problem: how to know which seed was which from session to session. It was very exciting to watch her attack the challenge before her.

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Figure 6.6: Karen’s data record in her logbook about her radish seed growth in different saltwater concentrations.

When asked what she learned from her project, she reported: “I learned that just because some things take time to grow doesn’t mean it won’t eventually grow (Karen I Wonder Article and I Wonder Conference, 8/15/02).” This is true in science and also in students. Karen took time to grow into the culture and the ideas of science camp, but eventually she did grow, and actually learned that plants can grow in some salt water, but not a lot. She began to enjoy the work on her projects, actually became a role model for the younger students and contributed in positive ways.
Karen was toward one end of the spectrum opposite that of Anthony in interest in science. Karen began disinterested and unwilling to extend her thinking or to individually challenge herself. It was with great effort that the teacher engaged Karen in a topic of study that she didn’t already feel she knew the answer to. Karen’s ideas about science were focused on the textbook and “getting the right answer”. However, after she began to “see results,” her interest increased and she began to participate more positively. Even when it is difficult to motivate students, it is important to continue to encourage them to challenge and extend their thinking.

Types of Prior Knowledge

The case studies presented here suggest that even though the students were able to pursue their self-guided inquiry to completion or closure, there was no single path or method that the students used to carry out their inquiries. Each student had his or her own individual needs and levels of experience with scientific investigation. As a result, their investigations were unique as well. Some students began with simple designs and elaborated on them as they continued to ask questions. Others stuck with their original project, but were able to correct their scientific misconceptions.

Despite the differences in individual students’ methods of investigation, the cases shared a common view of the importance of prior experience. In each case, prior experience (or lack of prior experience) impacted or shaped the nature in which the students participated in their individual I Wonder Project. The experiences that students bring to the process are important because they impact how the students will approach and tackle scientific problems. Some students will want to “go it alone”,
regardless of whether or not they are capable of completing it. Others will want
teacher reinforcement each step of the way. These differences are important for
educators and parents to recognize when planning a self-guided inquiry activity. Not
all students will be able to participate completely on their own, but with support and
encouragement at their level, they will be able to work through scientific
investigations.

Learning comes from interactions with the natural world as the individual case
studies might suggest. However, Wells, Chang, and Maher (1990) suggested a more
specific need for learning of new material to occur. They suggest that “each individual
knower learns through a process of interpreting or making sense of new information in
terms of what he/she already knows” (Wells et al., 1990, p. 2). In addition to actual
experiences with phenomena and media, interactions with others (within and outside
of our normal culture or social circles) impact how we use and interpret information
that is learned (Vygotsky, 1978). Prior experiences from any source will affect new
learning differently with each individual, as was shown in the six student cases
presented here. Some of the students were more greatly impacted by prior experiences
in their neighborhoods or with their families, while others relied upon prior
experiences from actual school science practice. In addition to experiences,
interactions with people within the primary culture and others outside of the primary
culture also affected the experiences and interpretation of knowledge by each of the
students.
Across the case studies, four types of prior experiences emerged: school science… experiences outside of school. This typography is not only an identification of the source of the prior knowledge; the different types of prior knowledge had different effects on students’ inquiry experiences during the I Wonder Process. Each of these types of prior experiences will be more closely examined and compared across cases in the following sections.

**School Science Prior Experiences**

The most common type of prior experience used by students was their school science experiences. The culture of school is different from many other types of student interactions. In school cultures, students usually do not have the freedom to determine which experiences they have or do not have. Therefore, students participate in a more formal culture, where they are instructed on how to behave and typically what they should learn (Wink & Putney, 2002). Each of the students reported a wide range of different school science experience, from not being able to describe science as a class (Jeff), to students who actively participated in hands-on activities (Anthony). Their individual experiences were important, yet more interesting was the impact of the prior experiences with school science on the I Wonder Project activities.

First, minimal school science prior experience was a common thread between both Jeff and Tabitha. Neither of these two students was able to cite past school science investigations or even science activities. Jeff referred to school activities during his interview, but none of them related to school science. Tabitha was also unable to recall school experiences relating to science, but she may have also been too
young to answer the question adequately. As a result of minimal school science prior experiences, each of these students experienced difficulty working with others during scientific investigations, understanding how to utilize scientific tools, and developing scientific investigations on their own. Specifically, both students needed to be paired with other more capable students when working on group activities and needed teacher scaffolding during their individual I Wonder Projects until they gained confidence in their daily procedures and logbook recording. Without teacher scaffolding of procedures, neither student would have been able to complete a controlled experiment, mainly because they had not yet experienced doing this type of experiment in school science class.

While some students needed extra assistance during their projects as a result of their school science experiences, others were able to work more independently because they had prior experiences with controlled experiments during school science. For example, both Anthony and Ariel reported having participated in some school science experiments. Ariel reported her experiences to be mostly limited to viewing her teacher demonstrate scientific investigations, but Anthony reported not only following scripted laboratory activities, but also completing a science fair project independently of science class for a school project. These varying experiences with school science led to two different approaches taken by each of the students. Ariel was willing to allow teachers to aid her procedure in the beginning, but once she was comfortable she wanted to determine her own path. Similarly, Anthony had a very
specific plan in mind and was not interested in teacher input or recommendations until he had reached a level where he could go no further on his own.

Each of these students reported a different comfort level with science, from “not liking it” (uncomfortable with it) to “I love to do science activities.” These individual comfort levels stemmed in part from the school science experiences (successes); the more successful a student felt in school science, the more confident the students were in pursuing scientific investigations individually.

**Home or parental involvement in science explorations**

Gee (2001) refers to the first language students learn at home as the primary language. The first culture to which humans are introduced is that of family or parents. This will become the culture that other experiences or knowledge is compared to throughout early life. In order for new knowledge to make sense to most students, it needs to be compared to experiences learned in the home (Dewey, 1910). Therefore, the science experiences to which parents expose their children will have a lasting impact on their understanding or comfort level with science. Almost all of the students reported having watched some sort of science programming such as the Discovery Channel, Animal Planet, or attending a science museum or other scientifically related activity. However, most of the students also reported little scientific investigation at home with a parent.

Several parents were interviewed about their reasons for bringing students to summer camp, as well as their individual science participation with their children at
home. All three of the parents interviewed reported bringing their students for additional academic enrichment over the summer months. However, only one of the parents was specifically interested in her child receiving additional enrichment in the area of science. Anthony’s mother wished her son to receive additional science enrichment, because he has shown interest in science activities at home. She reported that they often completed scientific investigations as a family. This was very different from Jeff’s mother and Teresa’s mother, who both reported having no science interest of their own, so no home science activities took place with parental supervision.

These reports also seemed to relate closely with students comfort level with scientific investigations. Anthony was confident in his ability to ask question and determine a procedure to investigate those questions. Again, this relates to Gee’s (2002) suggestion that some students’ primary language fits more closely with that of the formal or school language and aids the students ability to adjust to and feel comfortable with a more formal exercise, such as asking scientific questions. In contrast to Anthony, both Jeff and Teresa were hesitant to ask questions in the beginning, and even when they decided on questions later, they relied heavily on teacher input and guidance to determine their investigation procedures. Their lack of formal home language and school science combined to leave them without sufficient prior experiences upon which to draw for confidence and knowledge of how to carry out a science investigation.

However, in Teresa’s case her prior experiences with her mother did led her to the idea of studying mold in the first place. Her mother is a cleaning woman and
Teresa had occasionally accompanied her mother on cleaning jobs. Teresa commented on more than one occasion that she was interested in learning about mold because of the mold she saw growing in a bathroom that her mother had a difficult time cleaning. Teresa’s initial refusal to participate until she thought of a “worthy” question was unusual. The fact that her topic related to her prior home or family life for meaning and worthiness was not a surprising factor if we consider the importance of home life on social construction of knowledge.

Students’ Prior Beliefs about Scientific Work

Another area of prior experience that impacted students’ willingness or ability to participate in their individual I Wonder Projects was students’ beliefs about scientific work. When these six students were interviewed, they all had misconceptions about the work of scientists, ranging from “they didn’t have time to sleep because they were always in a laboratory” to “being famous because they were a scientist.” Most of the students’ beliefs about science had negative connotations, as was shown in Chapter 5. Lemke (1990) warned that students needed time to talk about science and to participate in science like scientists in order to appreciate science as a whole. This was the case for motivating students’ interests in completing an I Wonder Project.

The most common statement heard from students’ prior beliefs about science was that it was too hard for them. However, as they participated in scientific investigations and skill-building activities during summer camp, many of the students
gained confidence and a new appreciation for the work of scientists. Most students believed that they had to know the answer to their question before beginning so that they would get the “right answer”, much like what was seen with Karen in her case study. However, over time, students began to feel more comfortable with the exploration and learning as they went along. This also changed their perception of scientists as “all-knowing”, but they did persist in believing that scientists needed to be really smart.

The DAST test research explained in Chapter Two suggests that students must come into contact with real scientists and scientific environments in order to effectively change their perception of what science is and what scientists do. Without these experiences, students’ perceptions are based on the ideas they have heard at home, witnessed on television, or even learned in school. In order to change, students must experience science in a more true form to aid their understanding about the actual work of scientists.

Students participating in I Wonder did not complete the formal DAST test, but they were interviewed with questions similar to those found on the DAST survey. After the freedom of choosing their own questions and how to pursue their investigations, many students changed their perceptions and ideas about being a scientist and also their willingness to participate in scientific investigations in the future. In the beginning, none of the students reported that science was fun. However, by the final interview, only six weeks later, twelve out of the fifteen participants reported thinking that science was fun and that they were looking forward to doing
science in school in the fall. When I asked the students why they changed their minds, many reported that they enjoyed their summer and would like to do more science like this summer in school. Their summer camp experience changed the way they thought about science and doing science.

Neighborhood and Other Experiences Outside of School or Home

Another area in which prior experience impacted students comfort level with the I Wonder Project was neighborhood or other life experiences away from home or school. For instance, several students reported having attended a camp that was away from home for a week. The students often referred to this camp as they were giving evidence or creating explanations for other things they did or saw during camp. An example might be Ariel’s ability to communicate with Anna about whether it would hurt or not if the crayfish pinched her with its claws. Ariel was also able to use her experience with playing the piano at camp to further her ideas about her own project. Another example is Anthony, who had witnessed a magnet holding a car in the air before it was crushed. The magnet holding the car was very large, which might have led him to his original idea that the larger the magnet the better, which he later found to be not true.

Dewey (1910) states that it is important to allow students to experience things in the real world and then apply them to the classroom setting. In his school, students had a laboratory where they learned to build the materials they were studying. The I Wonder Projects are similar in a way, because they allow students to build on their
observations of things in the students’ natural world and bring them into focus in a classroom or more formal setting.

One third of the I Wonder Project ideas came from students’ experiences outside the home or school. For instance, Anthony’s work with magnets could have been a result of study in school or when he played with them at home. However, he reported being interested in the larger magnets like those used in a junkyard that was located near-by in his neighborhood (Anthony post interview, 7/15/02). Anthony reported his ideas came from watching at the junkyard, but other students’ ideas could have arisen from a variety of sources, including outside prior experiences. Teresa’s work with mold stemmed from an experience in the bathroom of an employer of her mothers. When she saw her mother struggling with the mold in the bathroom, it gave Teresa an idea for her project. She was able to observe the conditions in the bathroom and get ideas for how to proceed with her I Wonder Project.

Some of the students did not report many science activities outside of home or school. These students frequently needed additional assistance with their I Wonder Projects. For example, Jeff suggested that riding bikes with friends and doing tricks with the bikes might be science. And indeed, there is plenty of physics involved in riding a bike. However, Jeff did not choose to draw on these prior experiences with his project. Instead, he became interested in a mold project from reading about such a project in a former I Wonder Journal. However, not having had any prior experience growing mold or even observing mold, Jeff was unsure of how to proceed.
There seemed to be a difference in approach when students had had some prior experience with the topic, whether it was from observing or actually participating in an activity, prior experiences aided and supported students as they worked on their I Wonder Projects.

Conclusions

Each of the students participating in the I Wonder Project followed unique paths during their investigations of science questions. Some of the students worked alone and without much teacher assistance, while others required direct instruction. Among the factors influencing the paths was prior experience. As educators it is important to recognize that students are not empty vessels to fill, but that each individual has specific prior experiences which impact what they know and how they view the world around them.

In this study, the prior experiences of students fell into four types. These types represent the source of the prior experience (home, school, neighborhood, and informal experiences). These experience impact how comfortable students are with open-ended inquiry investigations. When students questions come from experiences they have had in school they tend to require more direct teacher intervention because they believe there is a right or wrong answer. When students questions come from observations in nature, student tend to rely on their own observation skills and have more confidence in their ability to investigate. Therefore, the types of prior experiences have a differing influence on questioning and investigation.
These findings are important because it moves past the constructivist ideas that “kids have knowledge that you need to consider.” The types of prior knowledge and experiences that students have is important and teachers need to be aware of these experiences when they ask students to participate in an extended open-ended inquiry activity because those experiences will directly impact the amount of teacher instruction and the type of investigation students develop. Students prior experiences are more than just misconceptions to be corrected, but also knowledge that affects their investigation ability.

Because of the unique paths taken by each student, it is important that the methods used by teachers and students in this process be more carefully examined. To examine interactions in further detail, tape recorded conversations and student logbooks were utilized. There were two main types of interactions at work during the I Wonder Process: social and verbal interactions. Social interactions will be described in more detail in Chapter 7 and Verbal interactions in Chapter 8.
Social interaction in the context of this project included daily communicative contact between teachers and students and among students. Social interaction occurred primarily between teacher and student interactions and student-to-student interactions. It is a common criticism of self-guided inquiry that students are all expected to understand and make progress on their own, but then are not always successful. Teachers sometimes believe that open-ended inquiry only needs to be supported with one level of guidance. One of the difficulties in the summer camp was the wide range of ages and skill levels. Some children were able to independently write sentences and paragraphs, while others needed a great deal of help with spelling and what to write next. Because of this diversity in student need there needed to be individual interaction style with each of the sixteen students working on the projects. Students in the summer camp program were successful in part due to the varying levels of teacher provided support, as explained in the teacher-student interaction section below. Students were also successful because they were allowed the freedom to pursue
investigations in the social manner of their choice, as explained in the peer-to-peer interactions section below.

**Teacher-Student Communication During I Wonder**

One of the difficulties in the summer camp was the wide range of ages and skill levels. Some children were able to independently write sentences and paragraphs, while others needed a great deal of help with spelling and what to write next. Because of this diversity in student ability, individual interactions with students required a varying amount of support. As the teachers began to understand the different learning needs of students, it was quickly recognized that varying amounts of structure would be necessary for each of the students.

The individual experiences with prior science activity, process skill ability, and interest were all factors in how much guidance students would require. Following the continuum for inquiry teaching described in Chapter 2, the teachers and counselors aided students by interacting with them in three main ways: structured, guided, and open-ended. Structured inquiry (Tafoya, Sunal, & Knecht, 1980) interactions involved the teacher aiding student work with step-by-step instructions. Guided interactions involved the teacher aiding the student with questions for clarification or affirmation. Occasionally, the teacher would provide information about how to proceed or next step guidance. Finally, open-ended inquiry (Martin-Hansen, 2002) interactions involved the teacher periodically checking with students to be sure they were still on track the teacher did not need to provide next step directions. Each
teacher/student interaction will be explained in detail with examples in the following sections.

**Structured teacher and student interactions**

The first of these support styles was structured teacher and student interactions. Structured inquiry activities in typical science classrooms require the teacher to provide the students with: the scientific question to be explored, the materials, the procedure to be followed (Tafoya, Sunal, & Knecht, 1980). Sometimes the teacher even provides enough information that the students know the answer to the questions that they are exploring. Structured aid by the teachers during I Wonder had some similarities and differences to the structured activities of classrooms. In contrast to structured school science, the I Wonder Process structure did not select the student question, and only aided the students with some of the materials they may not have thought of because of their limited experiences. Similar to the classroom structured inquiry, structured interactions during I Wonder did provide some of the procedures for students to follow step-by-step. These similarities and differences will discussed in this section.

Teachers provided structured aid by providing experimental design scaffolding or guidance. Structured guidance was particularly needed when students had limited or no prior science experiences. This structure worked for students with limited science process ability because it provided a framework for them to learn about how to do science, which they had not previously experienced.
These design scaffolding instructions or structured questions seem to go against the grain of what “true” self-guided inquiry means. However, both of these students and others in similar situations went on to complete their projects and felt a sense of accomplishment from their work. They didn’t seem to notice that they received more instruction time from the teacher and counselors, but actually relished the time and influence and often asked for this level of interaction from the teacher. In some cases students need more teacher interaction than others; the key is make sure that students are still being encouraged and challenged beyond their current levels. Four of the youngest camp participants were the main focus of structured teacher interactions, but on occasion, this type of aid was required by a range of student ages.

Working one-on-one with students was essential for completion of the projects in the limited available time. Children often lacked direction and did not know how to proceed. Many of these children did not have experience in an open learning environment and needed teachers to provide structure in the discovery process. Note in the following transcript that the teacher tried to help an eight year-old student determine the next steps while comparing silly putty and flubber. This transcript section begins after a brief discussion between the teacher and Jen about her past progress and her current project needs. Jen thought she might be done completely, so the teacher began to discuss other things that Jen might compare.

T- Jen, listen to me. So, here watch and I’ll show you. You can take a magic marker and you can write your name on a page in your notebook, like this. Or you could do this. You can write (Jen) and you can take a piece of flubber... Jen-Do I put it under here?
T- You flatten it out. And you just do it like this. What do you see?
Jen- My name.
T- And what direction is it?
Jen- Backwards.
T- What else do you see on here?
Jen- The lines of the paper, right? So write what happened….
( more experimenting with teacher and student)
T- Can you do the same thing on your own?
Jen- Um-huh.
T- Call me when you’re done (8/5/02).

In this section of transcript the teacher aided the student with an experimental design scaffolding procedure, or structured procedure which seemed to be needed by that student at that particular time, given her age and skill level, to aid her on focusing on independent work. She was able to complete the same types of activities using the other materials and recorded her findings in her logbook (Jen notebook, 7/26/02).

Structured design scaffolded instruction was also helpful in providing a methodology for students who, given their lack of science experience, were unable to create such a methodology. One example came from a student who was unable to set up a controlled comparison experiment. The following transcript section begins with a discussion between Jeff and the teacher about the setup of his project where he was going to compare the different types of mold that grows on different substances. The following transcript begins with Jeff explaining that he wants to study how mold grows on different substances.

T- That’s a good question. You’re on the right track here. We need to talk about how we’re going to set it up though. Do you want to just test one piece of bread or do you want to test lots of pieces of bread?
Jeff- I don’t care.
T- Well, what do you want to do? You get to choose, that’s the fun of it. Do you want to do one or more than one piece of bread?
Jeff- More than one piece of bread.
T- Ok, so, let’s say we have three pieces of bread, are we going to have, what are we going to do? Are we going to do the same thing to all three or are we just going to leave?  
Jeff- I want to do a different projects on each . . . (tape recorded 7/30/02).

Teachers can use structured questions to assist students who have weak or underdeveloped critical thinking skills. Notice in the transcript above that the teacher has asked specific structured questions to help guide Jeff in developing his plan (e.g., “Do you want to just test one piece of bread or do you want to test lots of pieces of bread?”). The transcript shows that Jeff needed forced choice questions in order to progress further with his project. Jeff’s pretest reveled that his general and science skills were considerably lower than his peers. Jeff had not yet learned the ability to think critically but was able to follow a scaffolded or structured process, which is one reason the teacher was asking such structured questions. Another reason for the structure comes from observations of Jeff in open-ended activities. He was frequently frustrated to the point of quitting or becoming disruptive to others, until someone could help him. From these observations, we decided the best plan for helping Jeff have a productive experience was to provide structure in the form of scaffolding experimental design instructions.

The results of scaffolding design instruction-

Further along in the discussion, notice Jeff took more ownership in the project than he did earlier in the conversation. He went from saying “I don’t care” in early discussions, to specifically responding in the following example. Jeff and the teacher continued to discuss the set-up and began to describe the third substance, pasta.
T- And chips. And are we going to test one more thing? We were going to test one more thing, weren’t we?
Jeff- Pasta.
T- We were going to do pasta. So we have three pieces of pasta, right? And this time we’re going to do what to that piece of pasta?
Jeff- Plain.
T- We’re going to leave it plain. And this one’s going to have?
Jeff- Water (tape recorded 7/30/02).

In this transcript, Jeff has shown he has a general understanding that what we do to the first two substances we must also do to the third. The teacher was required to talk less and ask fewer questions to come to a conclusion for this series.

Students who received structured interaction from the teacher were able to move to a more guided approach, described in the next section, or complete their project with continued step-by-step instructions. Most of the students were able to work from a guided approach at least some of the time. Usually, once the students went through a step-by-step procedure once or twice with the teacher, they were then able to manage to repeat without constant teacher presence.

Case study of Jeff- Impoverished science experiences and the necessity of a structured approach

Several students stood out as needing more assistance than others, but none more so than Jeff. His examples stated during the structured interaction section began to highlight some of his needs as far as challenge and encouragement within the self-guided process. From observations of his science process skills and interactions with science materials and activities during summer camp, it was clear that he had not had much prior experience with scientific investigations. During skill building activities it
was apparent that Jeff was unaccustomed to working with hands-on science or controlled experiments. For example, when Jeff was asked to work with two other students during the Statue of Liberty activity (the students were asked to set up a controlled experiment comparing different natural environments: dry, moist, salty-moist with different substances that were part of the Statue of Liberty: copper and iron to try to reproduce the bluish coating that the statue has) he was unable to understand why there had to be a control and different variables tested. The following excerpt from the researcher’s observations highlights Jeff’s lack of prior knowledge of how to set-up a science investigation, or why a controlled comparison is necessary.

Many students had difficulty setting up the experiment because they didn’t follow the step-by-step instructions well. However, most of the students at least understood why they needed to have some of the cups without liquids and without some of the materials. One exception to this was Jeff. He was working with Ariel and she kept trying to give him instructions. Jeff was intent on making sure that each of the cups had exactly the same thing in them. When I asked him how he was going to figure out which environment the bluish tint was formed in he couldn’t. I tried to help Ariel explain to him that he needed different substances in each of the cups to compare what happened in the different environments. He wasn’t sure why we would want to do this. He continued to add saltwater to each of the cups until I came over to sit with the two of them and helped them step-by-step get the experiment ready. It will be interesting to see what kind of project Jeff wants to do, because he doesn’t currently seem to understand the nature of a controlled experiment (researcher field notes 7/12/02).

Jeff was not very good at following directions or sharing equipment during the first few weeks. The counselors and I quickly noted that Jeff would only work well with a select few of the other camp participants. Jeff’s key complaint about others he worked with was they were “bossy”. He needed someone who could guide and aid without always telling him what to do, a tall order for another young participant. Based on these observations, it was understandable that Jeff needed some individual
interventions during group and individual activities. These individual interventions came in the form of structured aid, such as step-by-step instructions, frequent monitoring of progress, or even structured questions. Often the researcher and or counselors had to aid Jeff with his self-guided project. The next excerpt from the researcher’s field notes gives an example of how this happened.

Today JoAnn needed to work individually with Jeff in order to get his observations of his mold completed. I observed her actually drawing and labeling the table for Jeff’s observations. After this was completed she went through each of the bowls, (the bread with water, the bread with chips and so on), to help him determine what to write. He was excited to see some of the mold growth, but resisted making formal written observations. It was only with individual structured questions from JoAnn that he was able to complete his observations and stay on task (researchers field notes 8/2/02).

This structured interaction was not always necessary, and as Jeff’s experience dealing with science activity increased, so did his ability to move away from the rigid structure to a more guided approach. As time went on, Jeff began to accept and adapt to the sharing and exploring culture. He would wait patiently while the directions were explained before manipulating the supplies on the table. He took turns with the equipment and allowed others to participate with him during the activities. For example, as highlighted in the next excerpt when the students were working on an activity called “how much water in a baby’s diaper,” Jeff worked very well with another student, shared equipment and even encouraged her in way not seen before in Jeff.
“Teresa and Jeff worked well together encouraging each other to get more water in. They each took turns measuring the water in the graduated cylinder and adding it to the diaper. Jeff in particular seemed fascinated by the amount of water the diaper could hold. However, both still struggled with observations. This was the first occasion were Jeff did not need adult intervention during an activity (Researcher field notes 7/24/02).

In addition, his individual participation changed over the course of the summer camp; he would ask questions, we would not have to beg him to work with partners, and he even began to ask questions about why things worked the way they did. These changes were slow and were not noticed by some of the camp counselors until the last week of summer camp. One counselor came up to me and said, “Did you notice that Jeff was actually sharing today and we didn’t have to beg him to” (Researcher field notes 8/15/02). As Jeff continued to experience science in this new way, he began to change his participation as a member in the group and during his self-guided inquiry project.

Guided teacher and student interactions

The second type of teacher-student interactions was through guided inquiry methods. Tafoya, Sunal and Knecht (1980) defined guided inquiry as used in the structured school science classroom, the teacher presents students with a question, materials, and a framework of how to proceed with the exploration. The major difference between guided inquiry and structured inquiry is that students are usually able to determine the “answer” to the structured investigation, without really doing the exploration, while in the guided exploration there are sometimes more than one
possible answer. Guided inquiry as used in the I Wonder Process had some similarities and differences to the guided activities of classrooms. In contrast to structured classroom guided activities, the teacher did not provide student questions, or determine student materials or procedures. During the I Wonder Process, when students needed clarification or suggestions, the teachers would extend student thinking by asking them questions to help the students determine the answers on their own. Occasionally, the teacher helping a student in a guided interaction would give actual next-step suggestions, but it was up to the students to determine the following procedures. The teacher facilitation of guided inquiry interactions are discussed in this section.

Not all of the students needed structured interactions, however, many of them needed guidance to help them get started or to clarify their ideas. The students that tended to receive this type of guided interaction were capable of making solid observations and could usually make a comparison between two different items. Often times the students were able to verbalize the type of help they needed. When they could not, the teacher was able to ask guiding questions to help the students clarify what he/she was trying to say or do.

The transcript section below illustrates a guided interaction between the teacher and one student. It is a short section from the first scientist meeting where the students are sharing their ideas with the larger group. Ken is sharing his initial questions and trying to develop focus with the teacher.
T- What do you want to learn more about?
Ken- How much energy to do dogs have?
T- How much what?
Ken- Energy do dogs have.
T- Energy?
Ken- Yes.
T- How are you going to test that?
Ken- I don’t know.
T- Well let’s start with what materials do you think you need? (tape recorded 7/15/02).

At this point the teacher guided Ken by allowing him to verbalize interest and maintain uncertainty. Because his question was broad, the teacher needed to help the student focus. She asked him to make a list of materials he might need to guide him into developing a clearer project goal or question. The teacher’s field notes stated: “working with Ken was difficult today, he really wanted to do a project with his new dog which is understandable, but he was trying to answer questions that even I thought would be difficult. I will need to talk to him more tomorrow to attempt to help him generate a more specific question” (7/15/02). Ken was able to generate a broad question, but he later found the project difficult to complete, because he needed to utilize his dog at home while working without any peer or teacher interaction to collect data.

There were many examples of guided teacher and student interactions that did not include the teacher working as closely with the students. Ariel, a nine-year-old female, needed less guided help, but yet, still wanted affirmation about her work. Ariel read an article in a past I Wonder Journal about how a piano works and wanted to try to build one on her own. The following transcript describes a planning session with Ariel and the researcher for building a mini-piano.
Ariel- Um, I don’t know how to build one.
T- So, how can you find out how to build one?
Ariel- Um, I don’t know. You can take wood and use for the little table things to put the keys on.
T- Ok.
Ariel- And I know you can get like cardboard or wood to make the cover with.
T- Do you think maybe we should find what’s the step-by-step procedure on how to make it, a piano?
Ariel- I don’t know, how.
T- Okay, think about what are you going to do first?
Ariel- Take cardboard or the piano parts with the keys on.
T- How are you going to make the keys?
Ariel- With wood! (Tape recorded 7/30/02).

The transcript shows examples of two of the main reasons for guided interactions.

First, Ariel needed affirmation that she was on the right track. The teacher does not correct Ariel but asks her to continue along the line of her current reasoning with statements like “ok” and “what are you going to do first?”. In addition, the teacher also asks questions that will help Ariel clarify how she will proceed, “how are you going to make the keys?” The teacher is not providing an answer, only questions that will guide the student towards making an informed decision.

The results of guided instruction

There were two contrasting results to guided interactions with students. For some of the students, guidance in the form of clarification or affirmation was enough to complete their project mainly on their own without any structured assistance. The students who were able to develop a clear plan as a result of guided interactions with teachers were able to complete their data collection and the project. However, one of
the students who began in a guided approach did require a more structured approach towards the end of the project because of the difficulty of the task at hand.

Case Study – Ariel- Basic science skills led to need for guided instruction

Most of the students participating in summer camp did not need experimental scaffolding design instructions all of the time. However, the majority did need occasional supervision or guidance during group and individual activities. A student who represented this need was Ariel. From the beginning, she was capable in the basic science process skills and only increased her skills after participating in the skill building activities. Ariel described her school science experiences as having infrequent hands-on activities and a lot of science book reading. However she was impressed by her science teacher last year because “she had a really neat rattle from a rattlesnake on the end of her key chain that she used to get our attention. She also showed us some interesting science experiments” (pre-interview 7/9/02). Unlike Jeff, Ariel had some, however limited, science experience.

Ariel performed well on her process skills pre-test. She was able to list multiple observations—comparing and contrasting the two objects, her predictions were accurate and used evidence to support those predictions, and she used multiple methods to represent the happy/sad balls in the communication task. Each skill illustrated some basic ability to perform science experiments. In addition, when asked to set up a controlled experiment, unlike Jeff she understood the need for multiple variables to determine the cause.
In many of the early activities Ariel took the lead in design, regardless of her partner. For example, when she and her partner Ken were asked to draw a diagram of what they believed to be inside the ACME volume exchanger (described in Chapter Three) she started the dialogue immediately with the following discussion.

Ariel- I think that it’s melting like, like a gel like ice and then when it gets solid enough, every 24 hours, it kind of melts and then it begins water and it goes soft, it’s making water, and it’s dripping in half. And, then it comes out through the hose…

James- So you think there’s ice inside of it too?

Ariel- How do you add ice; if it’s wet? How did she add ice to it to make it work? It came from Iowa; it’s kind of hot in Iowa, how did the ice get here and not melt?

James- Because it must have been kept cold with water and ice to keep it cool.

Ariel- But the ice would melt. We’re talking like over a 100° in Iowa; like it’s hot in Iowa, and then it went on an airplane. How did it get on an airplane in all of that heat and not melt?

James- She added it this morning, maybe

Ariel- So what do you think?

James- That there’s little jugs of water in there and every time you put water in there, the jugs sort of like tip over and then the water comes out. More than it’s supposed to.

Ariel- Ok, so what happens if we do this again and there’s, only let’s say there’s two jugs in there and we do it again? We do it three times. How do we fill the jugs up inside there to make more water? (Tape recorded 7/26/02).

This discussion between Ariel and her partner James, shows that she was capable of critical thinking skills and recognizing when a different explanation was necessary.

When James was not convinced of her explanation, she asked “so what do you think?” Both students went on to make a drawing that involved the “jugs of water” idea from above with affirmation type guidance from the teacher as they were working on the drawing.
The ability to work independently, as well as her pretest skills, led the researcher to believe that Ariel would need little guidance during her I Wonder project. However, the project that Ariel decided on was quite complicated and required teacher questions for clarification as well as guidance for the next steps. The following example from the researcher’s field notes gives an example of how the teacher guided Ariel in the planning of her project.

Only one of the students seems to be interested in a true engineering project as was common in the previous I Wonder Journals. Ariel is interested in building a piano. She got the idea from reading a previous I Wonder Journal article where a student learned about a piano. She will need to do quite a bit of trial and error in order to get this project off the ground. She realized she needed different lengths of string to make different sounds, which was a good start. I made several suggestions of guitar strings and other types of wire today to help her conceptualize the strings in different widths, which she had not considered. We will continue to brainstorm equipment tomorrow (7/17/02).

This guided interaction of suggesting different widths was necessary to avoid frustration and to help Ariel create a working model of a piano. She might have been able to figure this part out on her own, but with guidance, she was able to move on quickly to the next steps of planning how to build the piano with the materials we have agreed upon.

Ariel decided on the guitar strings, which were different lengths and different widths to create some of the strings in her piano. However, once she had the strings, she experienced difficulty figuring out how to put it all together. She attempted some trial and error methods for fixing the strings to the plywood, however, none provided the tones she desired. The researcher then attempted to provide a working model, by purchasing a toy piano. However, in most of the modern toy pianos, the sounds are
produced electronically, not by actual strings. After dissecting the toy piano, Ariel discovered the circuits and other necessary mechanisms in a modern toy piano, which was interesting to her, but this did not help her finish her project.

Next, the teachers attempted to provide structured interactions with step-by-step aid to help Ariel complete her project. She refused the aid, and insisted on trying to work it out on her own. Ariel did not complete the building of the piano. However, in her project article, she did reference her new knowledge of modern toy pianos. In her words “I leaned how a piano worked. I learned that resistors are like sockets that help make the circuit in the piano. I was able to better understand how a circuit works because I got to take one apart and see how it works” (I Wonder Article 8/14/02).

Ariel was mostly interested in guidance when it helped her to move forward with her project. When the offer came from the teacher about how exactly to do something, she resisted insisting she could do it on her own. She and the researcher did learn that building a piano was not as easy as they originally thought.

**Open-ended teacher and student interactions**

Open-ended teacher and student interaction was the third type of teacher-student communication. According to Martin-Hanen (2002) open-ended inquiry is not a common classroom practice. In I Wonder open-ended interaction occurs when students develop their own ideas and only seek confirmation from the teacher. Open-ended interactions were observed regularly when several of the students realized they
had a “good idea”, (as deemed by their peers or teacher). Students would immediately begin planning their steps without teacher guidance or intervention.

The following transcript example is just one of many where the student told the teacher what they wanted to do. This occurred early in the summer camp, when students were sharing their planning ideas with the larger group facilitated by the teacher. Most students were able to state their ideas, and possibly some of the materials they thought they would need. However, there were several students who were soon ready to share a formulated idea. The following section begins with the teacher asking the students who wants to go first and Anna frantically raising her hand to volunteer.

T- Ok. Do you want to go first, Anna? Go ahead, Anna.
Anna- My question is, “why is a crayfish body shaped the way it is compared to a lobster?”
I am going to get a crayfish, more than one, and get a lobster. And then I can eat it after I’m done. Get a science book so I can learn more about both of them. Um, pay attention in time on how they move and learn more about the different parts of their bodies.
T- Do you have something else to add Anna?
Anna- Yea. See how fast the lobster or the crayfish can move. (tape recorded 7/23/02).

Anna then described her project in further detail. As is shown in the transcript, Anna did not need guidance or structured advice to continue. She had very specific ideas about what she wanted to accomplish. The teacher participated in the open-ended interaction by not asking specific questions, or even questions that would help Anna clarify.

Students also transitioned from needing a structured or guided interaction to a more open-ended interaction style. For example, one of the students asked the question, “what is inside flowers”. The student began working one-on-one with one of
the teachers and then moved to exploring on her own and sharing her results only with
the teacher. The following transcript is a portion of that type of conversation.

T- What are we finding?
Tabitha- The flower and the seed that used to be inside.
T- You’re trying to find the seed that used to be the flower?
Tabitha- The flower used to be a seed. Here feel this its the seed and its rough.
T- Why do you think that’s rough?
Tabitha- Cause it’s supposed to be wet, and its not, cause they, the petals need
something to drink. Then it goes up there into the petals.
T- Well how does this make the seeds dry? (tape recorded 8/7/02).

Notice the student begins to describe two different ideas, but she is beginning to make
the connections that the seeds she is finding in the flowers will grow to be new
flowers. She also knows from past experiences that seeds which do not get water will
not grow. The teacher here is trying to allow Tabitha to describe what she understands,
including her misconceptions, to get a better idea of her thinking. Tabitha goes on
from this point to ask the teacher if she can take the seeds from this flower and plant
them to see how they grow and she did that independently of the teacher’s guidance.

This type of open-ended work sometimes came early in the students work, and other
times, it came after structured or guided work. For some of the students, this was their
first experience with inquiry and asking their own questions, and they were unsure of
how the process worked. Once they learned it was okay to make mistakes or to try
different things, they began to want to work more independently, as well as try
additional ideas that they came up with, not that the teacher was guiding them to.
Case Study- Jane- Advanced science background

Unlike Jeff, who needed step-by-step instructions, and Ariel who needed clarification and guidance in her planning, Jane was able to design, implement, and conclude on her own, with little to no intervention on the part of the teacher. Much like the example in this section of Anna who was ready with her topic and materials almost from the start, Jane too was able to conceptualize and modify her plan as necessary throughout the I Wonder process.

The key element for a teacher student open-ended interaction style requires that the student is capable of designing and carrying out the experiment with no guidance from the teacher. During the pretest on science process skills, Jane preformed exceptionally well compared to her contemporaries. She was able to make both quantitative and qualitative observations of each and between each of the two objects. Her predications were supported by accurate evidence, and she provided a lengthy written analysis of why she believed the happy/sad balls to be different resulting in different performance. In addition, Jane could be counted on to work with many of the students who had minimal science experience and help them design a controlled experiment like the ACME volume exchanger, or make predictions about why something worked the way it did.

Jane was also unique in her interest in what we were learning in I Wonder summer camp. For example, when we completed the activity about predators and prey by dissecting an owl pellet, the students were asked to write a story about the relationships they had learned about. Most of the student struggled with this activity
and quit after writing a paragraph or creating a drawing. But Jane went home and
finished her story and then typed it out for the counselors to read. Jane, on several
occasions, commented that there was not a lot to do at home and her main guardian
was her sister who worked many hours. This might explain her willingness to continue
to work. She was interested and didn’t have other options for her evening at home. But
nevertheless, she did go above and beyond when it came to completing and
participating in experimental work at camp.

Jane was excited and motivated by the opportunity to ask questions and
develop a plan to carry out an investigation. She was one of three students who when
presented with the opportunity said right away “I have a really cool idea”. Jane was
interested in learning about the different materials that comprise ink. This project idea
stemmed from a short chromatography activity students participated in as part of the
regular camp activities. In the following transcript section Jane is given her first
opportunity to share her question and material list during a scientists meeting.

Jane- My question is what about what different colors do chemicals make.
T- Ok.
Jane- And I was thinking maybe if I could test different color inks I could find
different chemicals. And um like purple and blue look different on the page.
T- That might be one way. Anybody else have a suggestion?
Jane- I want to look to see what colors make up the different colors inside ink
pens, different gel pens. Take a pen and write it on a piece of paper and then,
and then use a gel pen it don’t matter what color and see how they look
different.
T- Yeah, maybe.
Jane- Then maybe to make different color ink. Maybe. And the other thing I
could do like we did with the marker. Remember with the nail polish? Yea,
with the nail polish. Do you remember?
T- I remember that. How do you do it? (tape recorded 7/30/02).
Jane goes on to further describe her project. She is so excited while she is explaining that she sometimes stumbles over her words. However, in her notebook, her procedure is clear as she has made notations step-by-step for herself.

From Jane’s scientists notebook:

**My Project**
Date 7/24/02
Time 3:00

Black ink- what are the different colors in black ink?
Filter paper, 5 water based black markers, magnifying glass, pipette

Step 1: Draw X with each marker on different filter papers
Step 2: Take the pipette and put the same amount of water on each X
Step 3: Take the magnifying glass and study the different colors that are being separated.
Step 4: Record different colors on a piece of filter paper if that is the only kind of paper you have, but if you have regular paper record on that (Jane’s logbook).

Jane went on to continue to test different colors of markers and learned that the water-based markers were better for color separation than the gel pens that she liked to write with. She kept a detailed record that made sense to her about what she found for each of the pens. The researcher did try to suggest several different ways to record information, but Jane was happy with her current results. It was clear that she had maintained appropriate records when she turned in her final I Wonder article that contained a data chart showing some of the differences she found. She was successful at completing her project without teacher suggestions.
Peer-to-Peer Communication During I Wonder

Peer-to-peer interaction is the third and final social interaction reviewed in this chapter. Regardless of the student interaction type, students were able to complete their projects. However, in order to do so, some students relied on peer assistance more than others.

As time went on during the inquiry projects, many of the students began to show interest in not only their projects, but also the projects of others. This peer-to-peer interaction was encouraged but not forced by the counselors and researcher. As the students worked on their individual projects, they were seated at tables with either two or three students at the same table. Each of the students had their own tasks to complete, but were also able to communicate with their peers about questions or observations they had made. During group investigation times, students were usually asked to work in pairs or groups of four. The researcher and teacher used these interaction times to determine good working groups for the individual project time. During the large group activities, students were usually given a data chart, a written prompt or a verbal question to respond to in their journals. Most of the students completed these activities in their journals. For some, this would be the only time they recorded data in their journals. For others, this was just the beginning of data collection and recording. Students were not required to record in their journals but it was encouraged.

Students were split into two groups for the individual projects, to give them more space and personal attention from the teacher and researcher. These groupings
were created to keep students working on similar types of projects working together at
the same table. For example, two students working on growing mold were assigned to
the same group and table. However, a few of the table and group assignments were
made based on our attempt to get students to interact positively with one another.

Three types of student peer-to-peer interactions were identified: independent,
dependent, and multifunctioning. Students who wanted to work individually and not
share their findings were categorized as “independents”. “Dependents” behaved
differently because they were willing to share their work and were usually interested
in the work of others. Finally, “multifunctioning” students drew behavior from both
independent and dependent student types. These three styles are elaborated in the
following sections.

Independent

Independent student behaviors were described primarily by field notes and the
students’ notebook since these students were rarely “caught on tape”. Out of
the group of fifteen students only about three of the students met each of the main
characteristics. Independent students were characterized by three primary traits. First,
these students mainly wanted to work alone without peer or teacher interactions. They
used their notebooks almost exclusively for scientific observations, used descriptive
observations, and had almost no peer interaction, even though they were sitting next to
or across from others (See Figure 7.1). Second, these students would respond to
teacher or peer questions, but would typically go back to their own projects almost
immediately. They were usually “put out” by the interruption, and needed the time and quiet to concentrate on the task at hand. Third, they were typically the last students to join in a peer or class observation. For example, when the students were all gathered around one of the fish tanks to see what had happened to the crayfish, these students had to be asked to join in the discussion. When they did join in, they were usually quiet or one of the last students to comment verbally in the group setting.

Figure 7.1: Logbook record of James, an independent working student.
Finally, an interesting and valuable observation was that these students rarely judged other students’ ideas as incorrect or “dumb” as other students did. However, they typically did not accept ideas different than their own and rarely changed these ideas based on peer input.

Jane’s work with her project and her peer interactions are an example of this style. Jane created her project idea from a chromatography activity that the students completed as part of the regular camp investigations. She wanted to learn more about the different colors that comprise pen ink. Jane preformed at a high level as she recorded her findings in her science notebook, but she was rarely recorded on tape. On the front of Jane’s notebook she wrote “Stay out please”. Inside the notebook where she was instructed to record her name and address, she wrote “if you find this journal, please do not read any further and return to me”. Also inside Jane’s journal were detailed descriptions and drawings for all of the large group activities as well as her own individual project.

She took to heart her early interview comments that “scientists keep their findings to themselves until they know something for sure”. She did not want anyone reading her notes in her journal-including the teachers. She rarely shared her findings or observations, unless directly asked. However, she was proud to share her results in her final paper and at the I Wonder Conference at the end of camp. Her statement was
“now that I know the answer”. Her final conclusions were that the “gel in the ink protects the ink from separating”.

This description would also hold true for the others in this category. It was difficult to encourage group participation with these particular children. When working on group activities they would typically work independently of their partner and then when they were done, would ask their partner what they found. They were not confrontational, nor did they really contribute to the general learning environment for anyone but themselves. However, they did complete all of their tasks in a timely manner and with great success.

Dependent

This category of peer interaction describes a social group of students and several key characteristics describe this particular group. First, these students worked best with others, and almost never wanted to work alone. These students found it difficult to stay on task with their projects for any length of time without confirming with a peer or teacher. In most of their individual work there was rarely an entry in their notebooks, unless it was suggested by a teacher or peer. In Figure 7.2, notice that the student recorded the information from the board as requested by the teacher, and then never returned to answer the questions or record any data. Second, these students were usually the first to ask peer or teacher questions. For example, they were often found asking “what do you think about…” on tape to peers sitting at their respective tables. Field observations of this group often refer to their interest in others’ work
almost more than their own. Third, this group of students were usually eager to contribute to class or group observations. These students are social and don’t want to miss out on any of the class or individual discoveries. Finally, these students were typically easy to sway to another’s idea without much effort or proof, even when the student had the correct answer to begin with. Approximately five of the students utilized the dependent interaction style.

Figure 7.2: Anita’s logbook entry where she did not fill in data or answer the questions.
There are many examples of this type of peer interaction. In the following example, Ariel and Anna who are working on different projects but sitting at the same table, share some observations about Anna’s crayfish project. The excitement in Ariel’s and Anna’s voices as they talk about what they are seeing, brings over one of our dependent style students to find out what is going on. In this transcript section, Anna has removed her only remaining living crayfish from its tank to measure its growth and to make some quick observations.

Ariel- Is it alive?
Anna- Yea, if it’s sitting here moving it’s alive.
Ariel- Cool. It will pinch you. Look at it.
Anna -Ok, careful. What’s it doing?
Ariel -Look it’s scared, it’s really scared.
Anna- I’m trying to get it back in.
Teresa- You’re going to kill it.
Anna- Look, look how fast he moves under water.
Ariel- Maybe it helps to walk backwards because you’re not that heavy in the water.
Teresa- And he also does what in the water?
Anna- Swims.
Ariel- It don’t look like it. It looks like he walks.
Teresa- Watch him in the water. Oh, he just did a flip!
Anna- That’s how he turns around.
Ariel- He went like this, he was right side up and then he went like that and did a flip in the water.
Anna- Remember in the paper it said he’s very active at night? I wonder if he does stuff like that at night (tape recorded 8/2/02).

Notice it didn’t take long for Teresa to come over from a nearby table and want to join in the fun. Also, notice that in this transcript, it was the students who really kept the conversation going by adding additional information. Teresa’s observation about the crayfish flipping and Anna’s calm reply suggests that she has seen this behavior before, even if Teresa had not. In addition, Anna’s use of reading information from the trade books provided helped her to add additional information to keep the
conversation going. Not only did they continue to talk about what they were observing, but this conversation led to a completely unplanned investigation which ended up involving many of the students in the room, since most of the classroom lights were out for a short period of time.

Another common type of dependent peer-to-peer interaction or conversation came in the form of peer suggestions. The following transcript illustrates how peers shared each other’s work and other peers added suggestions or asked questions of the scientist’s project in question. This is important, because the dependent style does not always mean off task behavior as some of the characteristics might suggest. The following transcript is from a table scientists’ meeting where the students were still in the planning and developing stages of their projects and were still trying to modify their questions and plans into a researchable question and project. Ariel had the task of describing Teresa’s current ideas about her project and then Teresa fielded questions from the other peers at her table about her ideas.

Ariel-The name of the project, the name of Teresa’s project is “Frogs”. The materials that she needs is a tent, rock, temperature, wrench and tadpoles. And, she needs to draw pictures. She needs to draw pictures to answer her questions. Ok, she’s going to draw pictures of their growth, is that what you’re going to do?
T- Anyone else have a suggestion?
Anna- Teresa, do you think you could add two different tanks and maybe put heat in one tank and not heat another and see if they grow faster or slower in the heated tank?
Teresa- They can grow in both tanks ‘cause their water is cold. There was not water there and it’s cold, wasn’t it?
T-So you don’t think they need heat to grow?
Teresa- No. They need a light, a lamp.
T- Anita, do you have a suggestion?
Anita- If they don’t have heat will it keep them from growing?
Teresa- No (tape recorded 7/23/02).
It is clear in some places that Teresa didn’t know much about tadpoles yet, and some of her peers are trying to help her understand that they believed she would see a difference in rate of growth between cold and warm environments. Teresa later explained that she didn’t want to kill any of the tadpoles and was worried if some were cold they would not live. This interaction shows that the students were conscientious about not hurting one another’s feelings. No one pointed out to Teresa that she wasn’t making sense. When Anna was unable to get Teresa to understand the controlled comparison, Anita tried in a different way to get Teresa to do the same thing. In addition, this is an example of how quickly dependent students’ ideas can be swayed. Later in this same transcript Teresa, began to understand and agree to the controlled experiment, suggested by her peers.

Multifunctioning

This style was reflected in the interactions of the remaining seven students. These students are similar to the dependent students in many of the social aspects, and similar to the independent students in the individual work ethic department. These students moved easily between independent self-guided work to work with others. They showed detail in some of their journal entries, and lack of detail in others. There seemed to be no particular explanation for why some journal entries were more specific than others. Specifically, the large group entries were the best entries with the most consistent data. For example, Figure 7.3 shows an example of a class activity where the journal entry was completed. For most of these multifunctioning students
there was more data recorded in their notebooks about their individual projects than seen by the dependent students, but not quite as much as the independent students. This group was able to toggle between individual and group work easily. They were often seen stopping in the middle of something to check with a nearby peer or teacher and then moving right back to work. These students rarely got up and moved to another table to explore what was going on unless directed to by a teacher or a peer asking for specific advice from that individual. However, this group did work better when there was a group of peers nearby to check with. When asked to work alone at a table they accomplished far less than days when peers were available for consultation. This group of students were usually the ones who suggested a peer observation or activity. “Hey come look at this”, “I found something really cool”, were common, but they expected their peers to “go away” after looking. Finally, these students tended to hold their own beliefs as fact until confronted with enough evidence to show them they were incorrect and then they would be willing to consider alternate possibilities.
The nail tuck the color of the penny.

A little color on the nail.
Summary and Analysis of Social Interactions

There were several different types of interactions going on throughout summer camp. First, the researcher felt it was important to develop a community of scientific learners. In order to do so, five primary characteristics needed to be embedded into the culture of the group: (a) sharing ideas, (b) value of individual and group participation, (c) learning to develop and ask questions, (d) a common language about science and scientific methods, and (e) developing an agreed upon set of rules. Sharing ideas was important to help students recognize that all student suggestions were important and valuable to transmit different ideas from person to person. In addition, students had to learn how to make the transition between working as a group to working individually so that they could complete a project that was of interest to them. Many students were willing to work in a group, but felt initial hesitation working independently. Next, many students had not had experience posing questions for investigations. Allowing students the opportunity to do so in a group environment helped them to prepare to do so individually. Also, creating a system for sharing scientific findings or results in a notebook or verbally was established. Finally, rules were developed and adhered to by the teachers and students for safety and consideration.

Next, teacher and student interactions were described and individual examples were provided. The teacher-student interactions came on several levels: structured, guided, and open-ended. Structured teacher-student interaction usually involved the teacher providing step-by-step instructions for the students to follow in order to complete a project. Guided teacher-students interactions allowed the student freedom to chose the procedure, but allowed the student to get help on next steps, clarification, or affirmation of progress. Finally, open-
ended teacher student interactions occurred when students had a solid plan and did not need intervention of any sort from the teacher.

Each child needed different types of interactions at different times depending on where he/she was in the planning research phases of the projects. The interaction levels of the teacher follow closely the levels of inquiry teaching in science. Often times in the classroom we overcompensate and structure activities for all students instead of just the ones who have a need. The students that needed less direction were more challenged in this environment because the teachers did not describe step-by-step for them what they should do. Likewise, students who needed this type of assistance were not struggling because the teacher was able to provide this type of assistance. It is important for science teachers to keep in mind that often it just takes some guiding questions to get students moving in the right direction toward a more open-ended and realistic approach to doing and learning science.

Another type of interaction that is commonly left out of the typical science classroom is that of peer-to-peer interactions. There were three different peer-to-peer interaction styles observed during this study, independent, dependent, and multifunctioning. The independent students liked to work alone, rarely talked to other peers, recorded findings in their scientific notebook without teacher direction, and had to be convinced to join group observations while working on their own project. The dependent student rarely worked well alone, talked to those at their table about each of their findings, rarely recorded in their scientific notebook unless instructed to by the teacher, and was usually one of the first students to join in a group observation. Finally, the multifunctioning students were able to toggle between there two interaction styles. They could work alone or with peers, they would sometimes remember to
record in their scientific notebook, but at other times would have to be reminded by the teacher. These students usually suggested the group observation opportunities.

Usually for safety or management issues, students are not allowed to move around the room and ask peers questions. However, there are many students in our classrooms who might benefit and learn just as much from this style of interaction. Likewise, when we force students to interact and work in groups, it is difficult for those who would prefer and work better given the opportunity to work alone.

There are several ways this information can be useful for teaching. First, while lesson planning, every effort should be given to develop activities that students have choice or the option of groups and group size. For example, some students may choose to work alone, or only with one other partner who might have similar independent styles as their own. They may only want someone to check with occasionally. Or, students may choose to work with a larger group in order to hear as many possibilities as they can to then make an informed decision about what they have learned. Second, students can be given a range of choices for assessment purposes. Some students are independent and would prefer to work alone and turn in a paper or written assignment about what they learned, while others may want to create a class presentation about what they learned to share with everyone. Given these choices students are more likely to be successful because it matches their individual needs as a learner and socially. Finally, even though students are working on similar activities, it does not mean they all have to accomplish the final goal in the same way. Allowing for individual and group creativity is important for building a society of learners and thinkers. If all
students are learning the exact same thing in the exact same way, how do we teach for
diversity of thinking? It is important that we begin to reassess the way we teach
science for all in our classrooms to make sure that we are giving each student the
individual advantage that he/she needs to be successful thinkers and doers.
CHAPTER 8

THE TYPE OF SCIENCE TALK DEPENDS ON THE TYPE OF SOCIAL SETTING

Inquiry and the National Science Education Standards (2000) suggest five learner guidelines for inquiry in the classroom. Four of these five points expect students to evaluate, explain and communicate based on evidence. The findings in this study show that in order to do that, many students need prior or current experiences from which to draw their evaluation, explanation and communication. Deep, long-term understanding does not come from a single, shared experience in the classroom. The majority of explanation conversations from this study are small group or one-on-one conversations between teachers and students, demonstrating that pivotal answers come from student questions based on experiences they have had or observations they have made on their own. It is important to encourage these questions as a basis for the rest of their learning.

As was described in chapter five, the children and adults were involved in daily science and social activity. During this time, students talked with adults and each other about the science activities in which they were engaged. These discussions, and how they led to scientific understanding or even misunderstanding is the focus of this chapter. Verbal interactions took place during every activity including, moving from space to space or lunch.
free time to time to play. However, the researcher was mainly interested in those interactions that led to talk about science that occurred mainly while participating in investigations or scientific activities such as I Wonder.

This chapter analyzes the five primary types of talk that students and teachers utilized as part of their project. The communication analyzed in this chapter was examined within the framework of scientific talk as described by Gee (1997). However, there are some distinct differences between the summer camp context and that of Gee’s 1997 study. Three of the primary differences were a.) affluence and school experiences, b.) type of inquiry used, and c.) social context of the study.

The group of students studied in Gee’s (1997) research of student discussion types were from a second grade classroom in an “affluent town west of Boston” (p. 1). The topics of their discussions were significantly advanced or “ahead” of the same area’s urban students (p. 1). The students participating in this study’s summer camp were of mixed ages, not from a single grade. In addition, none of the students were from affluent school districts. Most of the students were from urban or rural school districts with limited funding for new educational opportunities. As a result, these students had a limited exposure to scientific experiences in or out of school.

Another important difference between Gee’s population and the I Wonder students was the type of inquiry studied. In Gee’s second grade classroom, all of the students were engaged in structured inquiry: the teacher led the students step-by-step through their studies and discussions. In this study, students worked on a variety of
self-guided inquiry projects. Teacher-student and student-group interactions were limited but ongoing and individualized.

Finally, the social context of Gee’s study and this study differed greatly. The second grade students had a social history of completing science activities with the same teacher. The summer camp students had no prior experiences together and were forced to build a common language and community in a short period of time. These important differences frame the context for gaps and discrepancies in types of science talk found in the summer camp setting when compared to Gee’s study.

As mentioned previously, Gee outlined four types of talk, (a) design and debate, (b) anomaly talk, (c) everyday speculation, and (d) explanation talk. In addition, prior experience talk, a type of science talk that was not described by Gee, was prevalent in summer camp discussions.

The discussions observed in this study revealed several important factors: 1) design and debate discussion may take varying forms, but is still prevalent in early discussions of open-ended inquiry; 2) anomaly discussions as defined by Gee did take place in this setting; however, not typically during self-guided work, but more frequently during a group activity; 3) everyday speculation discussion among students in this study was consistent with Gee’s findings and that students reduced their observations to language or experiences they used daily; 4) explanation talk experiences were consistent with Gee’s findings and that teachers had to help scaffold student learning in order for them to relate observations to actual scientific ideas; and

\[\text{18 A more detailed description of Gee’s science talk is provided in Chapter Two of this}\]
5) prior experience talk, not previously defined by Gee, was observed more than any other type of talk in this setting, and was relevant to students’ ability to plan, carry out, and complete their projects.

Design and Debate Talk

Gee (1997) describes design and debate talk as a common type of scientific discussion that takes place when “one’s colleagues can always attempt to attack one’s effort at each and every stage of the enterprise—one may have designed badly, discovered (inferred, used logic) badly, or explained badly” (p. 7). For example, if students don’t agree on the findings of their peers, they may suggest that the reason the results came out the way they did was because of an error in set-up or procedure, not because a different result is a possibility. Gee found these types of conversations as part of large group discussions, often stemming from students using similar methods but finding different results.

The students in this study each had a different project and utilized different methods, therefore discussions of the type observed by Gee were limited. However, design and debate conversations took place during several of the skill-building activities when a large group observed/used the same methods. One of the first instances of design and debate occurred when students were asked to explain the following: there was a box with a funnel at the top and a tube coming out the side; a teacher poured 400 milliliters of water in the funnel and 2400 milliliters of water came dissertation.
out the tube, what mechanism needed to be present to allow this to happen? The students drew diagrams of their explanations and were asked to verbally describe how the machine worked. The transcript below is a debate between two students that is facilitated by a teacher.

T- Ken and Tina, “what do you think is going on?”
Ken- There’s ice inside.
Terry- You think there’s what?
Tina- Ice inside.
Terry- How did they get the ice inside without it melting?
Ken- Cold water.
T- What do you mean? You think there’s ice inside, tell me how you think it got in there.
Ken- Put a fan inside to keep it cold.
Terry- Put a fan inside to keep it cold? Well, how would you keep the fan going?
Ken- Put a plug in there.
T- Put a plug in there, but as you can see it’s not plugged in anywhere. So how would you keep that ice cold? And where would you put the ice at (Tape recorded 7/26/02).

Notice a student, not a teacher, asked for justification of ice being inside the box. Terry debated with Ken by asking Ken to explain how he thought ice would stay cold inside the box and later in the debate he asked how Ken could keep a fan running to cool the ice. These two students continued to debate and Terry concluded that there was no cord running from the box to an electrical outlet, so ice inside the box couldn’t be a reasonable explanation for the extra water coming out. Other student groups debated the same issue. This experiment was designed to encourage design and debate discussions, so results were somewhat artificial.

Design and debate discussion did not occur in any other instance in the students’ general discussions of self-guided work there were no instances of
opportunity for design and debate discussion. Students were asked to share their set-up and experimentations with those at a table with them, but usually other students “assumed” expert status of that student or depended on the teacher to ask questions about methods. Students did not challenge the design of another student’s work. In many situations, the students heard one another sharing work with their teacher and receiving positive feedback; this was “proof” enough that another’s design or implementation was sound.

Students engaged in debate by providing suggestions to one another regarding improvements in project design. This debate contrasts with Gee’s experience because of the self-guided nature of the summer camp projects. Peers and teachers engaged in this debate by sharing ideas and suggestions with a student for further self-guided study. For example, early in the summer camp, students were asked to share their initial ideas with a partner before proceeding with their self-guided projects. In a “reporting session,” students were asked to share what they learned about their partner’s project. In the following transcript, a student gives a report and the group of four makes comments and suggestions on the project.

Ariel- The name of the project, the name of Teresa’s project is “Frogs.” The materials that she needs is a tent, rock, temperature, wrench and tadpoles. And, she needs to draw pictures. She needs to draw pictures to answer her questions. Ok, she’s going to draw pictures of their growth, is that what you’re going to do, Teresa?
T- Anyone else have a suggestion?
Ken- Teresa, do you think you could add two different tanks and maybe put heat in one tank and not heat another and see if they grow faster or slower in the heated tank?
Teresa- They can grow in both tanks because their water is cold. There was not water there and it’s cold, wasn’t it?
Ken- So you don’t think they need heat to grow?
Teresa- No. They need a light, a lamp.
T- Anna, do you have a suggestion?
Anna, If they don’t have heat will it keep them from growing?  
Teresa- No.  
T- That might be an interesting addition to your project?  Teresa, that might be an addition to your question that might be interesting (Tape recorded 7/23/02).

The students in the transcript tried to help Teresa design a controlled comparison as part of her design. Teresa understood their comments as “what the tadpoles need to survive” instead of “comparing different living environments”, thus leading to more debate. Their debate contrasts Gee’s debate and design, as described, because students were able to debate and design in summer camp before results were available. This leads to the conclusion that debate and design discussion has a place in open inquiry, albeit a different place from that envisioned by Gee. This type of sharing and communication is important to the open inquiry process because it helps students recognize additional possibilities about their own work and that of others.

**Anomaly Talk**

Anomaly talk, as described by Gee, is a type of discussion centering on unexpected results. This type of talk is usually sparked by a teacher or peer. In the summer camp, students were observed engaging in anomaly discussions in both skill-building group activities and in individual self-guided work. A discussion of these experiences and their similarities to Gee’s observations is provided below. During a group skill-building activity, “snail races,” one student commented that maybe the snails were not moving fast because they were hungry. We proceeded to feed the snails blueberries and the following conversation took place:
T- Watch the top of his head.
James- The blue stuff goes up there inside of his head.
Tabitha- The juice.
James- He’s sucking up the juice up his head.
T- He’s eating the blueberry?
Tabitha- Yea.
T- Wow. Look at his head. What do you see in his head when he eats? Watch how he eats.
James- I see a little wavy thingy. Something in is head.
T- Yea, what do you think that is?
James- The juice
T- Why the juice? (tape recorded 7/18/02).

The anomaly as perceived by the students was that they “saw” blue in the head of a snail. Students did not expect to see blue in the head of a snail, and assumed that it was blueberry juice flowing through the head. It was a reasonable assumption for the students to make, given the color of blueberry juice, however it was difficult for the facilitator to change this assumption once it was embedded in the minds of the students. The anomaly was actually due to blood flowing through the snail’s head, however students were focused on the blueberries the snail had recently ingested. As in Gee’s experience, students continued to discuss the anomaly without linking the anomaly to the scientific explanation for the scenario. This session became a debate between teachers and students. The students kept asking teachers to “just look at their heads, you can actually see the juice if you look” (Researcher logbook 7/18/02).

In addition to group skill-building anomaly discussions, individual anomaly talk was also observed. Their descriptions of unexpected results from their investigations led to some interesting conversations: one student who was growing
mold observed a sample of “red mold” growing on cereal. The student had used a red marker to label her samples and some of the dye from the marker leaked into her bowl of cereal; when the mold began to grow it appeared red. The following transcript is between her, another student who is studying mold and their teacher.

T- Well what do we have here?
Terry- I have some red mold
Jeff- You can’t have red mold, there is no red mold, tell her!
T- Terry, why do you think you have red mold
Terry- Just look at this red mold on my cereal.
T- Terry what color marker did you use to label your samples?
Terry- Red, but what does that have to do with it?
Jeff- It made your mold red
Terry- No it didn’t, the rest of my mold is not red (tape recorded 8/8/02).

The anomaly in this situation was the presence of perceived red mold. As in the group experience, and in Gee’s study, students continued to discuss the anomaly and were unable to identify the correct scientific cause until the teacher intervened. Once the teacher suggested that the red mold might have had an influence, the students came to the conclusion that the red mold had dyed the white mold. This ability to conclude a finding that contrasts with Gee’s results due in part to the teacher’s intervention.

Everyday Speculation Talk

Everyday speculation talk, according to Gee, is when students reduce a scientific discovery or observation to its most basic and non-scientific parts, common language and knowledge. Instead of learning something new as a result of an activity or investigation, students’ existing knowledge is just reinforced. Gee believed that everyday speculation talk was not necessary for understanding and developing
scientific ideas. However, during an open-ended inquiry project everyday speculation talk is essential for students to develop and understand ideas. Students participating in self-guided projects need to feel comfortable with the concepts in order to continue to question and explore.

In everyday speculation talk students will rarely use new terminology for the first time unless aided by the teacher or a more experienced peer. Second, students try to explain what they are observing in terms of what they already understand about the world before applying to a new situation. Left on their own, students will speak in their own language to remain comfortable. Everyday talk has value, which is allowing students to make observations based on their own prior experience.

This study is consistent with Gee’s findings about everyday speculation talk. For example, in the transcript below, a student in a group skill building activity discussed findings about a flashing ball with his teacher. The machine was a small plastic ball with a red light that flashed when two metal plates inside of it were in contact when the ball was touched. Students could observe the outside of the ball, but not the inside. Their task was to explain what they thought the inside of the flashing ball contained.

T- What is your explanation?
James- There’s a flashlight and there’s a long thing with a button and it’s a metal thing touching or working on it, he’s just put his finger on it, can you see it? Do you see that metal thing? There’s another one. See it?
T- Ok. So what’s inside though? You described the two things on the outside James- Two batteries and a flashlight
T-Why two batteries?
James- So the flashlight can work (Tape recorded 7/22/02).
The everyday speculation was that the student believed there was a light source in the flashing ball. His prior experience with small light sources was a flashlight. When asked what was inside, he emphatically stated that it was two batteries and a flashlight. The teacher was curious about why he said “two” batteries and the student replied “so that the flashlight can work.” The tone used by the student was that everyone knows flashlights need two batteries to work. This was consistent with Gee’s assertion that students will not continue to search for scientific explanations when they think they know the answer. Once the student decided there was a flashlight inside, the whole machine made sense to him because a flashlight needed two batteries.

In addition to the group- skill building everyday speculation discussion, individual examples were observed. In the following transcript, a student sharing her project with some peers got caught up in the loss of a claw instead of the science of what was really happening in her experiment, which involved observing crayfish. When she had left the day before, there were three crayfish, each with two claws, living in a large container together. When she returned, there were two dead crayfish, a crayfish with one claw and several remnants of crayfish “skin.”

Anna- Hey, what happened to the one claw?
Ariel- Even with only one claw it’s still alive.
Anna- What happened to it though?
T- It’s molted. Do you know what molting means?
Anna- No, I mean what happened to it that it only has one claw?
T- Sometimes they lose them in a fight. Crayfish fight.
Anna- Why do they fight with each other?
T- For space, for their territory. Why else would they fight?
Anna-Cause they know you didn’t put them in their home (Tape recorded 7/31/02).
The teacher in this situation tried to use the “teachable moment” to explain molting, but the students were more interested in the crayfish with one claw. Therefore, consistent with Gee’s findings, students became fixated on the perceived area of interest instead of the science concepts involved. For the students, understanding why the crayfish had only one claw seemed to be more important than the reason it lost its outer shell, or the actual science. The students reduced what they were observing to a topic of discussion with which they were comfortable, consistent with Gee’s discussion of everyday speculation talk.

**Explanation Talk**

Explanation talk, as described by Gee, is when scientific content is defined and discussed with students in a way to bring about conceptual understanding. While describing explanation talk, Gee suggested that explanation types of talk are the least common between students. However, it is the most common influence of teacher-led discussions. As might have been expected, many of the young children did not have the vocabulary nor the life experience to explain scientific phenomenon they encountered; instead, they relied on adults to explain what was happening. This is one reason why some young children ask many “why” questions. The role of a teacher in explanation talk is to guide student discussions towards connecting scientific observations so they may understand science content.

The common behaviors of students and adults from Gee’s study held true in this study as well, however there were a few instances when students suggested
reasonable scientific explanations for their thinking. In the following example, we revisit the snail races. Students tried to create good “racing” environments for their snails before the snails were released. The students were asked to justify, “scientifically,” why they made their environment selections. The following two students worked together discussing the positives and negatives of possible environments for their snail: plain table, paper, or tin foil. The pair decided on the plain table.

T- Why the plain table Ariel?
Ariel- Because.
T- Because why?
Ariel- It has more friction.
T- It has more friction?
Ariel- So it can get a better grip on the ground.
Anna- And plus the tin foil might cut them.
T- Cut them. The tin foil might cut them.
Ariel- The tin foil might cut them, and when they push off and expect their body to move forward they like might slide backwards. (on the tinfoil)
T- Ok, alright. Sounds like a good reason to try the experiment this way! (tape recorded 7/18/02).

The students used their knowledge about the delicate nature of the snail, and the slippery nature of the slime that snails produce, to make their environment decision. The ability of the student pair to logically and sensibly describe their reasoning was an important step in their learning process. This explanation of reasoning is the first step towards explanation talk. It was uncommon to find student explanations without teacher guidance.

Another, more typical, example of explanation talk was similar to Gee’s examples in that it was teacher-directed. Students previously cited in this study were wondering about the exoskeleton of the surviving one-clawed crayfish and requested
an explanation from their teacher. The teacher begins with reminders of previous
discussions from other summer camp activities to help explain what an exoskeleton is
and why it is on the outside of the crayfish, to help students develop an understanding
of the function of an exoskeleton.

T- What did we talk about yesterday with Terry? What kind of skeletons is
that? Remember we talked about locust and their skeletons? What is that
called? Do you remember?
Anna-Shedding the skin.
T- That’s what they do, but what kind of skeleton do they have then?
Teresa- Um, ex, um.. exos..
T- You said it Teresa.
Teresa- Extraskin
T- No, exoskeleton. Ok. So, where is our skeleton at?
Ariel- In our body.
T- Inside, but their skeleton is on the outside. So, as we grow what happens to
ours?
Teresa- It grows.
T- It grows with us, right? As we get taller our skeleton gets taller. So what
happens to these animals when they need to grow?
Anna- They shed.
T- They have to shed or it called what? You’ve heard me talk about today. It’s
called, it’s an M word.
Anna-Molting (Tape recorded 7/31/02).

This explanation talk continued at length. This was an important “teachable” moment
because it involved several students, not just the student who was studying crayfish, in
the discussion. Because most projects at summer camp were self-guided, often these
discussions were one-on-one, teacher to student. In the above referenced example,
there were four students participating in the learning process. Also, during the excerpt
above, the teacher draws on recent student prior experiences before giving a science
term for the girls to try to comprehend. The teaching discussion revolved around
teacher-directed questions for the girls to consider and make part of their conceptual
understanding. This slow, methodical build to the explanation helped students build understanding as it related to what they had already observed. This was similar to the type of explanation talk Gee described for a large group discussion.

**Prior Experience Talk**

In this study, prior experience talk was the most common type of discussion observed in small group discussions among peers. Prior experience talk is considered any conversation between peers or students and teachers when the students rely on personal experience (in nature, at home, in school, on television or even reading a book) to describe or explain an observation. Prior experience talk is most commonly recognized in conversation as a point where students say something such as, “I know this because”, or “that’s not possible because.” Prior experience talk is not described in Gee’s study because within the context of his study, students relied on teacher instruction when trying to explain a scientific concept. This does not mean that this type of conversation does not take place in a regular classroom. Students often enjoy adding personal experience stories to conversations to show that they already “know that” or have “done that.” These types of conversations took place with or without a teacher present and became the basis for many student explanations and questions asked by students to other students giving a report, or as their inquiry question to research for the self-guided inquiry.

Discussions about prior experiences helped teachers understand why students brought specific ideas to camp and gave teachers additional information about the
lives and interests of their students, allowing them to plan their teaching more
effectively. Prior experiences often heard in summer camp was “when I was creeking”
or “my mom took me to this place where we got to see” or even “on ‘Animal Planet’”
they…” This type of talk was important for the teachers and peers to understand the
context of some student explanations. For example, one student told Anna that
“crayfish pinches didn’t really hurt.” When asked how she knew this, she said she had
been “pinched” by one during a camping experience. These types of conversations are
useful for a teacher to better understand the frame of reference of each individual
student.

It is important to recognize students’ prior experiences because it affects their
understanding or contextualization of scientific experiences. In the following excerpt,
one student is sharing her ideas with a teacher about what she is observing in her plant
dissection. The teacher heard this student describe “poisonous” milk inside flower
stems before and is hoping that recent conversations and explanations have changed
the student’s thinking. The two of them opened up the length of a sunflower stem and
look inside before the following transcript begins.

T- Look, look. What do you see inside there?
Tabitha- I can’t even see inside.
T- Look at that TH, what do you see?
Tabitha- It might be different things, poisonous milk inside.
T- I don’t see anywhere there’s milk. I see
Tabitha- Poisonous milk and
T- I see white stuff.
Tabitha- That’s poisonous milk!
T- What do you think that is, that white stuff?
Tabitha- It’s poisonous milk. Because, I looked inside in the flower and it’s
poisonous?
T- Na, it’s not poisonous. What’s it smell like? Smell it for me?
Tabitha- It smells pretty nice, like poisonous and milk.
T- Poisonous and milk? Do you think that maybe that white stuff is what gives those purple leaves their color? Do you think maybe that’s stored up food for those leaves?
Tabitha- Yea (Tape recorded 7/22/02).

The student readily agreed with the teacher’s suggestion that the white substance was food for the plant’s leaves. However, in subsequent plant dissections she continued to see the “poisonous” milk. When asked where she first learned about poisonous milk, Tabitha stated her kindergarten teacher told her “that the daisies on the playground couldn’t be eaten because they had poisonous milk in them (tape recorded 7/25/02).”

These prior experiences framed her understanding, or in this case misunderstanding, and guided her current thinking. In addition, when asked why she wanted to learn more about plants, she stated that she wanted to learn more about “the poisonous milk inside.” Learning Tabitha’s prior understanding of the inside of the flower helped the teachers to create activities which could help to modify those ideas. Without this knowledge it would have been difficult to change Tabitha’s conceptualization.

Students' prior experiences will influence their interest in continuing to develop scientific questions. Another example of prior experience talk can be found in a student’s reason for wanting to learn more about mold. When asked why she wanted to study mold, Terry replied:

Why does mold grow? I just wanted to know, I had a question for my dad, what does mold grow on. I knew that mold could grow on houses. My mom told me that. So I wanted to know where else mold could grow (Midterm interview 7/25/02).

She shares her knowledge about mold growing on houses with her partner in the following transcript section. Terry and Jeff both designed and were observing their
controlled comparison samples for mold. Each of the students chose different substances to grow mold on, but were finding similar results from their different substances.

Terry- I have gray mold, and green mold, and fuzzy mold.
Jeff- I have green mold and yellow mold and white mold, but no fuzzy mold.
Terry- Fuzzy mold is the kind that grows on houses
Jeff- No way
Terry- I know, my mom showed me in a house she was cleaning.
Jeff- where?
Terry- It was growing in the bathroom and it was hard to clean up (Tape recorded 8/8/02).

The students continued this line of discussion started by Terry’s explanation of her prior—and practical—experience with mold. Because of her interest and prior observations, she was able to discuss mold as an authority. Her experience also helped her design her experiment because she already knew that liquid would be required for mold growth.

Prior experience allows students to answer teacher and student questions knowledgeably. The following prior experience talk came from students who browsed through past *I Wonder Journals* because they referred to articles they had read. In addition to these articles, students also referenced science trade books when they planned their investigations or justified their observations. Students incorporated these readings into their general knowledge base and were then able to access it as prior experience. In the following transcript, students are comparing the types of food that tadpoles eat (in one project) to the food that crayfish eat (in a different project). The students are about to feed both creatures corn when the teacher interjects with a question.
Teresa—Put a piece of corn in the tank.
T—Why corn, Teresa?
Teresa—Because they eat corn.
T—How do you know they eat corn?
Teresa—‘Cause I eat corn.
Ariel—Oh. I think that was the page Anna was reading. It’s under crayfish behavior. I think it’s there. Let me see.
Anna—Crayfish are common streams like the one pictured here
Teresa—But I think..
T—Listen to Anna.
Anna—Under rocks or logs. They are most active at night. They feed largely on snails, algae, insect larva, worms and tadpoles. Some eat vegetation and various water plants. Dead fish, worms, corn and salmon eggs are also favorites of the crayfish.
T—So that’s how you got corn as an idea.
Teresa—How do they get in there? (refers to the corn pieces)
Anna—Well, can crayfish sometimes go, can be in a stream by fields and corn.
(tape recorded 8/1/02).

Notice that the students remembered reading about what crayfish eat, so they had a better reason for selecting corn than Teresa seemed to have (“they eat it because I eat it”). This use of prior information is important for students to continue to build an in-depth understanding about their topics. Even though students used the authority of the trade book and not personal experience in this situation, the information they already had was credible. The students are able to draw upon their prior experience, in this case reading a trade book for information, to answer teacher and peer questions.

Conclusions

This chapter analyzed four primary types of science talk between students and between teachers and students within Gee’s (1997) framework. A fifth type of science talk was identified as distinctive in self-guided project discussions. Each of the five primary types of talk will be reviewed.
First, design and debate discussions were different in self-guided projects than in traditional science classrooms because of their individual nature. However, they held an important role in student community building and sharing of scientific ideas as individuals added ideas and suggestions to one another’s project plans. Design and debate conversations in the I Wonder Project were pre-planned by the teacher and enacted by the students during the scientists meetings, where the children shared their ideas about their projects. The major difference between design and debate in I Wonder and in traditional methods was the use of these conversations before data or results were available. Students in I Wonder were required to share their design ideas for comment before collecting data. This allowed them to seek additional information from peers and teachers as well as to verbally defend their own personal ideas. Gee described the design and debate conversation as taking place after the students found different results and the debate usually tied to students assuming some problem with how the experiment was set up. This type of conversation was not observed during the I Wonder Project.

Second, anomaly discussions as described by Gee occurred mainly during whole group activities. The instances of anomaly talk described in this dissertation mainly occurred when students were confronted with a situation that did not match their own frame of reference which is analogous to Gee’s findings.

Third, everyday speculation conversations among students in this study were consistent with Gee’s findings. In several instances, students reduced their observations to common language or experiences to create explanations. In individual
conversations between students, the everyday speculations centered on “interesting” observations, instead of scientific observations usually because the interesting observations were manageable in their common language and experiences.

Fourth, explanation talk to bring about conceptual understanding of a scientific term or concept was unusual between students. Typically, as previously described by Gee, explanation talk required the input or direction of the teacher. In casual conversations, students are willing to share their common understanding and misunderstandings with other peers. It is only with the aid of a teacher that students truly begin to develop a deeper understanding about the vocabulary of science as was seen in the crayfish discussion with four students. However, it is important to note that students can make compelling observations without the assistance of a teacher when the projects are of interest to the students. As was shown in this chapter, when students had the prior knowledge and experience, they were able to begin to describe scientifically valid explanations which contrasted Gee’s findings.

Finally, prior experience talk not previously described by Gee, was the most common and productive talk for students to plan, carry out, and complete their individual projects. Young children verbalize their understanding of science to teachers and peers during self-guided inquiry work based on their prior observations or experiences with the understanding. However, in this study, prior experience talk was central to student conversations or at least was underlying in their individual interest and motivation to learn more. It is evident that there is not one way in which
students communicate their understanding of science. There are different levels of ability, depending on prior experiences or teacher scaffolding.

Teachers are often worried about the time it takes students to complete self-guided science investigations and how much the students will learn from their experience. However, when students are not given the opportunity to explore topics of interest, it is rare that a teacher will understand why a student’s experience does or does not allow him/her to understand a given topic. They are typically not given a medium for sharing their individual interests and prior experiences. One way to allow for this is to utilize methods developed by the Heron Network of teachers and schools for a shorter, more intense program like the summer camp mentioned in this study. This allows students to share what they already know or think they understand about the natural world and the opportunity to expand that knowledge.
CHAPTER 9
CONCLUSIONS AND IMPLICATIONS

Introduction
This dissertation began with the premises that in order to ensure that students have the opportunity to participate in more open-ended scientific investigations following the guidelines as set forth by the National Science Education Standards, multiple options must be available for teachers. This dissertation focused on an adaptation of one option – the I Wonder Project. The I Wonder Process used in Madison WI was described in detail in Chapter Two, while the changes for summer camp use were described in Chapter Three. Chapter 9 ties together the research questions and methodology presented in Chapters 1, 2, and 3, with the results and discussion presented in Chapters 4, 5, 6, 7, and 8.

Common I Wonder Practices
The I Wonder Project allowed students to select any question about science that they were curious about. The students began this process by creating a list of questions they had about science. What was interesting in this program was the difficulty students had in completing this task. Many students reported not having had
the opportunity to do this in their science classes at school. After they selected one
question from their list, they met in pairs to try to help each other plan an investigation
to answer their questions. With the aid of teachers and counselors, the students began
data collection and finally reported their results in a formal scientific paper and
verbally at an I Wonder Conference.

This process lasted six weeks, with students meeting daily to work on their
individual I Wonder Project, as well as other skill building activities to help increase
their ability to write and talk about the science they were learning. In addition, the
students meet twice a week with pre-service teachers to participate in small group
activities and to allow the pre-service teachers the opportunity to “try out” their
lessons with actual children. Finally, participating in many other social and science
activities with the camp counselors rounded out the students’ summer camp
experience.

Several aspects of this experience have been highlighted during this
dissertation. First, the effectiveness of the I Wonder Process was to improve
participants’ science process skills ability. This was shown by the statistically
significant increase in students’ scores from pretest to posttest, as well as through their
completion of the I Wonder Project. Second, the need for teachers to differentiate their
scaffolding techniques to the needs of individual children was shown through the three
different teacher student interaction styles (structured, guided, and open-ended). Third,
the importance of teachers allowing some freedom for children’s individual learning
styles with regards to peer participation was shown through the three different peer-to-
peer interaction styles (independent, dependent, and multifunctioning). Fourth, the benefit of teachers understanding the relative benefits of different types of talk that result from participation in a self-guided inquiry project was shown through the three types of communication (design and debate, explanation, and prior experience). Finally, the individual social changes and content learned by students as a result of participation in the self-guided I Wonder Project was shown through case study examples.

This chapter will elaborate on the students’ individual and group experiences in regard to initial research questions as stated in Chapter 3, as well as to suggest implications for teaching using the I Wonder Project in the classroom. In addition, several suggestions for future research will be highlighted.

Summary and Conclusions

In this section, the research questions are reviewed and conclusions are stated with regard to the 15 participants and three camp teachers.

Research Question One

Scientists generally work as part of a community, which has its own culture and ways of promoting their work. At the start of the study, students participating in the I Wonder Project did not have a realistic view of what science was or how scientists actually carried out their work. The first research question addressed this
view, asking “how did the I Wonder practices, activities, and communications promoted the development of a scientific literate culture with the students?” In this study, three aspects were needed to promote a scientifically literate culture: (1) students needed prerequisite levels of ability in science process skills appropriate for their age and development level, (2) students needed to acquire scientific habits of mind, such as questioning the world around them, and (3) students needed to support the interest and discoveries of other students, even if this means asking questions that might challenge the ideas of others. Several activities and experiences were provided to help students develop these areas and thereby promote a scientifically literate culture. These activities included skill building activities, building a scientific community activities, scientists meetings, and individual I Wonder Projects.

First, skill building activities were defined as experiences designed to increase students’ ability to work with scientific equipment as well as communicate scientific ideas such as predictions or conclusions. These skill building activities were essential for most students to develop and complete their I Wonder Project. For example, most students had difficulty correctly using the meter sticks (Chapter 4). However, after several skill building activities (measurement competition and How big is a big foot?), students were more at ease with not only using the meter stick, but also requesting its use during individual project work. This led to an increase in their science process skills which was useful during the I Wonder Projects.

Students participated in a different skill building activity daily during the first three weeks of camp, and then twice a week after they began full fledged data
collection on their individual I Wonder Project. Beyond skills such as observation and measurement, teachers and councilors also worked with the students during activities to help them acquire scientific habits of mind, such as developing questioning skills. For example, during the leaf activity where students were developing additional sorting skills, the teachers would ask the students to list questions they might want to know more about in regards to the leaves. Sometimes these activities led to differing opinions about the ways that activities should be completed or how data should be recorded. These support issues led to many discussions about collaboration in science, which ultimately led to building a scientific community where multiple views and ideas were valued.

The experience provided by these skill building activities allowed students to not only become more proficient in the science process skills, but also helped to build a scientifically literate culture among all of the students as they had participated in many shared experiences and could refer to these experiences when they needed to describe or refer to one or more of the activities.

Second, building a scientific community activities were important for cultivating a culture where students took control of their own learning and could share that learning with other students. Building the scientific community involved five primary practices: sharing ideas, valuing individual and group ideas and participation, learning how to develop and ask questions, building a common language about scientific methods and procedures, and developing an agreed upon set of rules. In the beginning of camp the students each came with different classroom science
experience. Some had participated in structured hands-on activities, others had mainly worked from a book. It was necessary to help students all establish common practices for engagement during scientific investigation. These primary practices were constructed through a variety of activities and conversations in which the students talked about their ideas and needs as individuals and as part of the group. Once students felt more confident in their skills they began to ask more questions. Building the scientific community was mainly important for developing good communication skills between peers and teachers and students with other students.

Third, scientists meetings were structured to provide a formal forum for scientific discussions of questions, procedures, and results. The first scientist meeting was structured to remind students of rules for sharing and the importance of valuing each other’s ideas. However, the students were also encouraged to suggest additional ideas to support and encourage further development of planning or investigation. The students were asked to participate as “scientists” sharing their personal ideas and challenges with each other. For example, when students shared their original plans for setting-up their individual I Wonder Projects, the students discussed materials and step-by-step procedures with one another. Then, other students were asked to suggest constructive feedback or to make suggestions for improvement on the plan. This interaction and sharing of ideas led to improved plans, more specific equipment lists, and most important, input from peers to peers about his/her work. This added to the development of a scientifically verbal culture between students. For example, students began to use the correct names of the instruments and tools for activities, “please pass
the meter stick”, or “can you hand me the graduated cylinder?” In the beginning of camp students were just grabbing what they needed without asking or even talking with their peers. By the end of camp, sharing equipment, using the correct terminology and cooperation were all part of the scientific culture of the group.

Finally, participation in the I Wonder Project helped begin to develop scientific attitudes and habits of mind among the participants. Many of the students began the program with the attitude that they couldn’t “do science” or become a “scientist”. Most students believed in order to enjoy participating in scientific activity they needed to be “really smart” or a “nerd”. However, after having the opportunity to ask their own questions, plan an investigation, and record their own findings, students began to understand a new definition of science. A definition of “science can be fun”, “you can learn science and have fun too” or that being interested in something is what is really important when wanting to participate in scientific activity. Because most of the students had not had prior experiences with open-ended or self-guided inquiry, this experience helped to widen their individual definitions of who could be a scientist and what a scientist does. All of these experiences and attitude changes further led to the development of scientifically literate culture.

Building a scientifically literate culture is an on-going, ever-changing endeavor. As students began to accept more challenges, their need increased for longer discussion times or additional scientific language. It was through individual and group sharing of ideas that the students learned how to interact with one another as students learning to really “do science”. Participation in skill building activities, activities
which build a scientific community, scientists meetings, and individual investigations all led to the formation of a culture of students who are able to: show prerequisite levels of ability in science process skills appropriate for their age and development level, acquired scientific habits of mind, such as questioning skills, and support the interest and discoveries of other students even if this means by asking questions that might challenge that other student.

Research Question Two

The individual I Wonder Project was one part of the I Wonder Process. The students participated individually on their self-guided study, but also participated as a small-group member or partner on many different activities leading up to the I Wonder Project. The second research question asked, “How do students experience participation as an individual as well as a member of the group at large while working on their self-guided inquiry project?” is answered by examining student participation individually as well as in a group in various settings. First, in accordance to students’ individual intellectual and social needs, the teacher interacted with the students in one of three ways: structured, guided, or open-ended. Second, the students participated as a member of the whole group in three different ways: independently, dependently, or multifunctioning. Finally, the type of individual interaction with the teacher did not directly relate to the type of peer-to-peer interaction used by individual students.

The first type of teacher-student interaction described in this dissertation was the *structured* interaction style. Structured teacher-student interactions usually
involved the teacher providing step-by-step instructions for students to follow in order to complete the project or activity. Structured teacher interactions were needed by several individuals because of lack of prior experiences with materials or actually doing science. In general, students did not need structured interactions throughout the entire I Wonder Process. Many students began with step-by-step instructions from the teacher and then moved forward with their own ideas. However, when new experiences were introduced these students would typically revert back to needed structured interactions from the instructor.

A second type of teacher-student interaction included guided aid from the teacher. Guided teacher-student interactions allowed the student freedom to chose the procedure, but the allowed the student to get help on next steps in the process, clarification of individual questions, or affirmation of self-progress. Several individuals needed this type of interaction during the entire I Wonder Process. The students who needed clarification and affirmation tended to require this type of interaction throughout the process.

However, two students who began the I Wonder Process relying on guided teacher-student interactions were able eventually to transition to working more independently, with the teacher supporting the student through open-ended teacher-student interactions. Open-ended teacher-student interactions occurred when students had a solid plan and did not need intervention of any sort from the teacher. The teacher would occasionally check in with individuals to make sure they were still making progress, or to ask questions to challenge the students to think more critically. These
students were by no means left on their own, however; they were allowed the freedom to try and to make mistakes and learn from them. Though there was always the risk that students would become frustrated working so independently, the teacher regularly checked in to be sure the students did not require additional guidance. Students who had clear purposes and goals in mind used open-ended teacher interactions.

In addition to interacting with the teacher, students also interacted with other students. There were three distinct styles of peer-to-peer interaction used by students within a group during the I Wonder Process. First, the independent students liked to work alone, rarely talked to other peers, recorded findings in their scientific notebook without teacher direction, and had to be convinced to join group observations while working on their own project. The dependent student rarely worked well alone, talked to those at their table about each of their findings, rarely recorded in their scientific notebook unless instructed to by the teacher, and was usually one of the first students to join in a group observation. Finally, the multifunctioning students were able to toggle between their two interaction styles. They could work alone or with peers, and even though they would sometimes remember to record in their scientific notebook, at other times would have to be reminded by the teacher. In addition, these students usually suggested the group observation opportunities.
Research Question Number Three

Students communicated their understanding (or lack of understanding) of science in several different ways. These uses of scientific language and process skills continued to develop throughout the I Wonder Process. The third research question considered “Which aspects of students’ scientific literacy (use of scientific vocabulary in written and oral settings, as well as process skills) change as a result of participation in the I Wonder Project?” Due to the lack of scientific vocabulary and skill level of most of the children, the use of scientific vocabulary in written and oral settings did not change significantly over the six-week period of time. This lack of progress is partially due to wide range of I Wonder Project topic areas investigated within the class so there was little time for the teachers and counselors to “teach” specific vocabulary or for students to use it as part of the camp setting.

In contrast to the lack of improvement in students’ science vocabulary use, students’ science process skills improved over six-week period. The students all completed a science process skills pretest and posttest that included six science skills: observation, sorting, measurement, estimation, prediction, and communication. As described in Chapter Four, students’ science process skills improved significantly from the pretest to the posttest on each of the six tasks.

First, *observation* skills improved as a result of participation in the I Wonder project. Most of the students coming to camp did not use all of the senses or counting to make simple observations. In addition, many of the students failed to make comparisons between the two given items during the pretest. However, during camp
activities and during the final posttest, students increased the number of observations, the use of multiple senses, counting when applicable, and used comparisons to describe the properties of the two items. Students also increased the number of observations during discussions about activities during other group skill building activities.

Second, sorting skills improved as a result of participation in the I Wonder project. Most of the students were able to group a set of objects in one way and describe that method. However, all but two students were unable to suggest another method or way to sort those same items. This skill was difficult, because if the students could not recognize multiple properties (observations) then they would have difficulty suggesting another way to sort. The students participated in several activities where identifying properties and then sorting were part of the task so that by the end of the I Wonder Process, students were able to create an original sorting scheme and then come up with at least two or more additional methods for sorting, thus improving their ability to sort by physical properties.

Third, measurement skills improved as a result of participation in the I Wonder project. Measurement was assessed using two different tools: the meter stick and the triple beam balance. Originally, the students had a range of abilities in the use of the meter stick. Many were able to use the English side, but not the metric side. Others seemed to have never been asked to measure before. In addition, none of the students reported ever having used the triple beam balance. After teaching the students how to use both objects properly and allowing time for practice, the students became more
interested in both objects. Almost all of the children found a way to incorporate the meter stick into their individual I Wonder Project. Several of the students even asked to use the triple beam balance to mass certain objects during their projects as well. By the end of camp, some of the students were still having difficulty using the correct units (cm or g) but most were able to get accurate readings from both tools.

Fourth, estimation skills improved as a result of participation in the I Wonder project. During the pretest, all of the students were able to make an estimation, though nine of the students were unable to state a reason or give a reasonable explanation for their estimation. Students worked on estimations during regular camp activities. Whenever possible, the teachers would ask the students to estimate and explain why that number could be correct of any number of objects, from the number of pretzels left in the container, to the number of skittles in a package. By the posttest, all but four of the youngest students were able to suggest a reasonable estimation supported with a reason.

Fifth, prediction skills improved as a result of participation in the I Wonder project. During the pretest activity, nine of the students randomly made predictions without consulting the available data. Other students had difficulty processing the data and ended up with unclear predictions as a result. Before each of the group activities, students were given some information about the activity and were asked to write a prediction about what they thought would happen. In the beginning, students were very concerned about being right, but by the end of camp they tried to use the available information to make an informed prediction. By the posttest, thirteen of the
students were able to utilize the available data to compose an accurate prediction of the weather.

Sixth, written communication skills improved as a result of participation in the I Wonder Project. During the pretest, most of the students struggled to write a sentence or two; those who didn’t write instead created drawings, most without labels. Throughout the I Wonder Process, the students were encouraged to write down their predictions, observations, findings, and conclusions. However, there was a wide range of ability to do so. For example, one of the students just entered the first grade and was only proficient in a few written words, not sentences. Students who were older also had difficulty expressing what they learned in writing, but not to the same extent as the first grader. By the posttest, many students included both labeled drawings and written text to describe the demonstration. However, this was the area that still needed additional work and practice for all of the students.

Students’ remedial skills in writing and verbal communication were apparent from the science process skills pretest and the initial interview sessions. Additional information about students’ weak ability to write and communicate their ideas was noted during the first several activities in the student work. Because of the range in age and ability levels it was difficult to focus on one specific area. However, the teachers encouraged the students to elaborate in writing whenever possible, added additional written and verbal prompts for students to respond to, and asked to students to represent their ideas with labeled drawings whenever possible. For the most part, students journal writing improved during their individual I Wonder Project, however,
all of the students could use additional work in the area of communicating their scientific ideas both in writing and verbally.

Research Question Four

Throughout the whole group and individual self-guided projects students were tape recorded to capture the types of science conversations or talk that was taking place. The fourth research question inquired “How were scientific methods learned, utilized, and transmitted to peers and adults in the classroom through oral language?” Science conversations were analyzed based on Gee’s four types of talk: design and debate, anomaly talk, everyday speculation, and explanation talk. Chapter Whatever compared the use of types of talk during self-guided inquiry versus traditional classroom guided inquiry and found differences in student talk between the two contexts.

First, design and debate discussions were different in self-guided projects compared to traditional science classrooms because of the individual nature of the former. However, students used design and debate during I Wonder Project scientists meetings in order to improve their inquiry design. The teacher in self-guided projects usually facilitated these conversations, unlike in the traditional classroom setting, in which students go nuts on their own? When I Wonder students were asked to share their design ideas with their peers, they were open to constructive feedback and a design suggestion or debate often would occur. This was in contrast to how Gee characterization of design and debate conversations as post hoc attempts to salvage one’s misconceptions in the face of disproving evidence.
Second, anomaly talk, everyday speculation talk, and explanation talk were largely consistent with Gee’s (1997) findings. The primary difference between the use of these types of talk in the present study versus Gee’s study was the settings in which they each occurred. For example, most of the anomaly talk heard during the I Wonder Process was during the whole group activities, whereas Gee typically found these types of discussions to occur more frequently during small group interactions. Similarly, though explanation talk occurred in both studies, Gee describes it as a teacher-led discussion most frequently occurring as a large class process so that everyone can have the information, Whereas in the I Wonder Process, explanation talk from the teacher occurred primarily as a small group or individual endeavor.

Finally, the type of talk most used by students in this study had not been previously described by Gee. Prior experience talk dominated the students’ explanations, reasons for choosing projects, and justification for results. The majority of student conversations about science were based on prior personal or school experiences. Students relied heavily on their home and school experiences to develop their original questions as well as early group activity explanations. With this particular group of students, prior experience was a large part of motivation and interest in any of the science activities in which they participated. They were usually very happy to repeat an activity they had done in school or even in recent summer camp activities. In addition, when given options, students often requested repeating some of the more interesting activities rather than trying something new. Many of the older students had to be challenged to think of a question for their I Wonder Project.
that they didn’t “already know the answer to.” Given the range in prior experiences, creating activities that were interesting to all was a real challenge.

Five Keys to Successful Self-Guided Inquiry

The results described in this dissertation suggest that successful self-guided projects require five primary elements: a scientific community, social interactions with teachers, social interaction with peers, science process skills, and verbal interaction. Each of these elements is important: without one, the total learning experience is diminished.

First, building a scientific community allows individuals to feel like part of the group. In addition, it begins to help transform the stereotypical views of traditional scientists (old, bald, white guy with a pocket protector), to a “science for all” view. It allows children to feel like their opinions are important and valued by the group as a whole. Finally, it helps students to learn to not only question their own ideas, but also the ideas of others, thereby becoming critical thinkers themselves.

Second, in order to support the individual needs of students social interaction with the teacher was need. The teacher as facilitator is still more knowledgeable about the methods of science, and the needs of individuals, than the students. It is important to gain a sense of students’ individual support needs so that during the planning and implementation phases, those students who will require a more step-by-step approach can be aided, while those who are ready to press forward alone might be allowed to do so. Working individually with students allows them the freedom to make choices
either to go forward or to wait for assistance. It also provides the teacher time to question students about their prior experiences and to use this information to challenge and support students in their endeavors.

Third, allowing students *social interaction with peers* was an important key to building community. Students will work with or without peer support, depending on their individual needs. Forcing students to work quietly and individually can be just as hampering as asking others to work and share with a group. It is important that students feel like they have the space to work independently, or cooperatively depending on their needs and desires. Some students will work alone one day and with a small group the next, depending on the mental and physical activity required of them. Allowing students this freedom allows them to feel as though they are making more choices in their participation, which usually aids in their on-going participation, engagement and motivation in the process.

Fourth, an appropriate level of *process skills* is just as important as the interest and motivation to do science. Students need to

make observations; pose questions; research in textbooks and other reference materials what is already known; plan and implement investigations; use evidence to explain questions; use tools to gather, collect, and interpret data; propose answers, questions, and predications; and communicate findings (National Research Council, 1996, p.22).

In order to do these things, they need to have prior experience with each individually as well as within a semi-structured investigation. Students need to believe they can do each of these things on their own before they will attempt to do them. Teachers planning to do open-ended inquiry need to be sure that students possess sufficient
science process skills, or they at least need to be prepared to work in a more structured fashion with those students who do not.

Finally, students need verbal interaction or the opportunity to talk with the teacher and with each other. There are many different types of science talk that have been described by Gee (year), Lemke (year), and others. However, when teachers, implement self-guided projects, they commonly leave out sufficient opportunity for students to regularly share their ideas, thoughts, challenges, and questions with one another. Sometimes those conversations do not move students forward in their thinking and then it is the responsibility of the teacher to make sure that the students learn the science behind their individual science inquiries.

Use of Self-guided Inquiry to Promote Scientific Literacy

This study aimed to describe the individual and group participation in a self-guided inquiry project. The students participating in this study were not attending because of their love of science. As a matter of fact, several reported only coming to camp because their parent or guardian “made them.” Yet, even with students who are not interested, they each not only found something interesting to study scientifically, but they each learned valuable lessons, as shown in Chapter 7. The fact that students were all able to complete their projects, even though they each had diverse needs and abilities moves the notion of “science for all” forward.
Two important findings need to be foregrounded for future use in the classroom or camp setting; teachers’ consideration of students’ prior experience, and individual needs and desires.

First, students come to school, camp, or even the playground with different prior experiences. We as educators can tap into this resource of interest and help students apply it in meaningful ways, or we can choose to ignore it for more standardized forms of study, such as whole class instruction with no opportunity for individual exploration. Students need to be given opportunities to make sense of the world around them under the educated eye of the teacher, parent, or counselor. Otherwise, what happens is students create their own explanations, much like Tabitha did when she stated that all plants contain poisonous milk. Without deep, challenging, and meaningful activities, Tabitha would still believe that all flowers contain poisonous milk. In addition, asking students where their ideas come from goes a long way towards understanding their thinking. Usually, their ideas actually come from prior experiences. It is important to understand these prior experiences so that we can help students move forward in their own personal understanding of the world around them.

Second, as educators and/or parents, it is not news that children have individual needs and want differing levels of aid from teachers or adults. We have all witnessed young children who struggled and struggled with a toy until they learned to use it correctly on their own, and another child in the same room who immediately runs to the nearest adult for help. However, at some point in school, students begin to
lose that desire to fight for their individual styles of learning. Children will need a
different amount of guidance from their teacher during a self-guided project. The
important factor is recognizing when to help and when to challenge, when to give in
and when to pull back. It is easier and quicker to just tell a student how to do
something; it is much more difficult to sit back and watch them struggle when you
know the answer. However, it is also important to know when struggle leads to
frustration, and when frustration leads to quitting. The teachers role in self-guided
inquiry is to guide, help, question, assist, aid, and to sometimes stand back and watch—it
can be pretty impressive!

It is important to allow students to work with peers at a level that is
comfortable to them. Not all students will get to the end of the project in the same
way. Some will do so by working independently and not sharing much of what they
are doing with others. Some will want to be involved in everything that is going on in
class to learn as much as possible. And others will decide how they want to behave on
that particular day when they get there. Sometimes, alternative assignments are good
for those students who want to get to the end goal in their own unique way. Dave
Jenks (2001), a Heron Network teacher, said it best: “Kids are not always interested in
what teachers tell them to be interested in. Kids don’t always remember to what
teachers want them to remember. Kids don’t always learn what teachers teach them.
Sometimes they learn other things” (pg. 126). Sometimes it is just as important that
they learn “other things” as it is that they learn what we want them to learn. And, just
maybe by learning other things, they will be more interested in learning what we wanted them to in the first place.

**Implications for Teaching and Learning**

The purpose of this study was three-fold. First, it is important to learn more about how scientific literacy is transmitted between adults and children, as well as from peer-to-peer so that this information can be used in the classroom. Second, there was a need to determine which practices are useful for developing a scientifically literate culture. Finally, to learn how students participate as an individual and a group member while they participate in a self-guided inquiry project is important to better understand how self-guided inquiry works. Each of these goals has implications for teaching and learning in the classroom or in an informal setting such as summer camp while utilizing self-guided methods.

First, there is a need for a range of inquiry in the science classroom. Though there is an accepted continuum of inquiry teaching strategies; however, students in the formal classroom setting are rarely given the opportunity or scaffolding needed to complete an open-ended exploration that can lead to a multidimensional understanding of science. It is important to note the differences between traditional structured scientific inquiry with that of more open and self-guided inquiry so that educators can begin to develop activities that allow for both methods. One way to allow for this is to use methods developed by the Heron Network of teachers and schools for a shorter, more intense program like the summer camp used in this study. This allows students
to share what they already know or think they understand about the natural world and the opportunity to expand that knowledge.

Second, students need the opportunity to participate fully in the range of scientific inquiry that can only be provided when they have the opportunity to choose their question, procedure and way to communicate their findings. INSES (2000) suggest five learner guidelines for inquiry in the classroom. Four of these five points expect students to evaluate, explain and communicate based on evidence. The findings in this study show that in order to do that, many students need prior or current experiences from which to draw their evaluation, explanation, and communication. Deep, long-term understanding does not come from a single, shared whole-class experience. The majority of explanation conversations from this study were small group or one-on-one conversations between teachers and students, demonstrating that pivotal answers come from student questions based on experiences they have had or observations they have made on their own. It is important to encourage these questions as a base for the rest of their learning.

Third, there is a need for students to be given a choice of group sizes when participating in self-guided learning. Whenever possible, cooperative groups or group size should be optional. For example, some students may choose to work alone, or only work with one other partner who might have similar independent work methods as their own. Or students may require a larger group network to ask for multiple perspectives so that they can make informed decisions about what they have observed
or learned. Allowing students the freedom to make these choices will provide a better working environment for all children.

Fourth, there is a need for multiple pathways to accomplish goals and assessments to match. Even though students are working on similar activities, it does not mean that they all have to reach the final goal in the same manner. If the goal is for students to participate in a self-guided inquiry, then it is important to be open to the range of possible methods of completion. Allowing for individual and group creativity is important for building a society of learners and thinkers. If all students are learning the exact same thing in the same way, there is little room for diversity of thought. It is important that we begin to reassess the way we teach science for all in the classroom to make sure that students are given every individual advantage to become students of the scientific community. In addition, if students are given the freedom to choose their methods for completion, there needs to be a range of choices for assessment to match these methods as well. Some students work more independently and would prefer to turn in a paper or written assignment about their work, while others could create a class presentation about their findings to share with the entire class. When the assessment matches the style of work there is a better chance that the students can be successful and feel confident about their work.

Recommendations for Future Research

This study was designed to compare multiple ages and group sizes while students were participating in the I Wonder Process. Because of the small sample size,
it was not possible to compare between students of similar age or multiple group sizes.

Effects on participation. Working within a similar research setting, summer camp with
more participants might lead to some interesting additional information. Many of the
students in this particular group came to camp with limited science experience.
Including more students with greater science experiences might change the group
dynamics in a way that would be noteworthy, especially with regards to peer-to-peer
conversations.

Additional research should be completed along these lines to better understand
the effects of poverty, race, and gender on process skill ability and ability to plan and
implement self-guided inquiry projects. This might be done in different school
environments (urban, suburban, private, and rural) as well as in a variety of different
grade levels in schools.

A long-term study following several students through school to see if their
attitudes and interests in science are changed by past participation in the I Wonder
Project would also be informative. For instance, after participation in summer camp,
following up with students to see what they remember during the school year, what
their teachers have heard the students talk about as part of class discussions, and
family interviews to see if interest in science changed over time. This could be
repeated for several years to determine the impact the experience had on students’
beliefs and interests in science.

Finally, a study that involved teaching pre-service and in-service teachers how
to implement this type of inquiry in their own classrooms would be interesting. When
teachers are asked to create a list of questions they would be interested in knowing more about they have similar problems that young children do. They typically have not experienced a self-guided study themselves. It is difficult to implement something you have not learned yourself. This study could be compared to the findings of the young children to find similarities and differences in social and verbal interactions between adults and students.
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APPENDIX A

SUMMER CAMP I WONDER JOURNAL
Discovering How Mold Grows

Jeff Age 8

One of the questions I wanted to know more about was what bread would do when left out in the open air, with nothing added to it. I also was interested in seeing what would happen when potato chips were added to the bread, would I get the same mold or would the chips work on the bread differently. I choose this question because I have seen mold grow on foods before and I was interested in learning more about what effects the growth of mold.

Materials
I used gram crackers, rye bread, wheat bread, lays chips, cheese, and water. I put each one of these items in a bowl and added water or chips to them. In one set of bowls I had bread by itself, bread with water, and bread with chips. This was done for each one of the items I used. In each bowl that water was added to, I made sure to cover the food.

Observations
With the rye bread I noticed that the one that I added nothing to and just left out was hard and brittle. The one that I added water to was different colored. It had yellow, green, brown, white, and orange on the bread. The one that I added chips to made the chips brittle and the bread hard. The gram crackers that had nothing added to them where soft, the ones with water got stuck to the bottom of the bowl and got separated, and the one with chips made the chips brittle and the gram crackers soft. I also was able to observe the cheese in each of these situations. The cheese and water got smelly and the water evaporated, the cheese by itself grew black dots on it and got hard, and the cheese with chips got hard, the cheese got stuck to the bottom of the bowl and the chips where brittle.

Conclusions
I learned form this experiment that water affects the growth of mold on bread. Because the water soaks up into the bread and makes the bread squeeze out the colors then it dries and separates. I also found that the chips made the bread, cheese, and gram crackers get softer because in the dark the chips will get softer and melt and make the items it was sitting on get softer.

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I want to say thanks for help from my camp councilors, Tracy and my fellow camper Typhani, who also did a project on mold. I would like to thank them for the support and help
The Great Living Frog

Teresa  Age 11

Questions
How does a tadpole grow in one week?
What do tadpoles eat and how they eat?
Will they eat corn? How does a tadpole move in the water?

I choose these questions because I like frogs. Because I like nature. I have a frog at home, but I wasn’t a tadpole when we got him, but he has grown. He has almost doubled in size. When I tap on the glass he comes over to be touched. So I wanted to know more about how he got to the frog stage.

Materials
I used a fish tank. We ordered the tadpoles from NASCO and they had to be shipped to us. We had to order them because we couldn’t find any outside. We couldn’t find them outside because it was the wrong time of year. They are already grown into a frog around here.

We ordered African Clawed Frogs because they grow so much faster and I would be able to see changes.

Observations
His tail wiggles and he feels soggy and wet. He has fins that help him swim. The gills help him breathe. He has a long tail that is about 4 centimeters in length. The tadpole can swim very fast. In order to swim he had to wiggle his tail and that would help him move through the water.

I wasn’t sure about what they eat, except fish food. I knew that Ahzia was feeding her crayfish corn and I thought I might try some of that too! The tadpole wouldn’t eat the corn. I had to break it into pieces. Stephanie told me that they were filter feeders and that is why the corn had to be broken up.

When I observed the whole tank of the tadpoles, I saw that when I got close to the tank they all swam away. Before I went over the tadpoles were just sitting in corners together not really moving far. When they want to move they can swim very fast. I also was able to see how clear the tadpoles were so I was able to see the heartbeat in the tadpole. This was very cool. The heartbeat was pretty slow. There was about 70 in a minute. I learned about the growth of the tadpole by reading a book The Tale of a Tadpole by Karen Wallace. I also got information off a website It’s a Frog’s life. Both of these helped me to learn about what stages will come next with my tadpole.

Conclusions
I learned that tadpoles are ugly. They really don’t look like a frog to begin with. It takes at least seven weeks for them to go through the cycles or stages to become a frog. They start off as an egg, then they become a tadpole with a tail. The tadpole begins to change by growing back legs, and then front arms. Then the tail begins to shrink and it becomes a frog.

To take care of my tadpole I will have to feed them everyday, change the water in the cage and use room temperature water. Make sure that I have rocks and plants for the tadpole to play in. I will have to continue to watch them grow. When they are full-grown I have to be careful they don’t get outside because they will kill other frogs that normally live around here.

Acknowledgments

Tracy, JoAnn, and Stephanie helped me work on my project. Anna and Ariel helped me to work on my project.

Fish

Tina  Age 9

Questions
What fish look like inside. How to tell if it is a guy or girl? How long fish live for. I wanted to know more about fish because I have fish and I wanted to know how to take care of them.

Materials
Books about fish, fish, scissors, gloves, tray to dissect on

Observations

I saw guppies and gold fish and a fish that looks like a baby shark. I saw on the baby shark 1 black line across it and the rest of the body is gray. I learned that male guppies have color. There is different kinds of gold fish with white tip on its nose, with a white bottom on its stomach and a regular gold fish with just gold all over.

When I dissected my Porgy fish I cut it open, next I made more cuts. It was hard to cut open because the fish was hard from being frozen. I saw the heart and gills. And I took the heart and gills out because the heart was hooked onto the gills. After you took out all of the stuff, we opened up the mouth and if you stuck your finger through the mouth you could see your finger by were the stomach would be. The fish smelled disgusting but it was fun to do. When I first cut open the fish it didn’t smell to bad, but the longer you are around it the smell got stronger.

Conclusions-
I learned that some fish you have to dissect to tell if they are a boy or girl. And that the backbone was connected to the top of the gills. There is more one kind of fins. The pectoral fins help the fish swim. When I felt the fish the scales were smooth going one way and hurt going the other way. This helps them to swim in the water without friction. The gills gave the fish oxygen to the blood, which is why they were connected to the heart.

Acknowledgement
Thanks to Mrs. Candy for letting me look at her books and her fish. Thanks to Stephanie for helping me cut open
Changing Moods

Anita Age 11

Questions

I wanted to know what different foods people eat each day and how their mood changes after eating. I wanted to know if there was a difference between their moods after breakfast and lunch. I wanted to know this because some people were angry and mad after breakfast and lunch and I wanted to know why they were like that.

Since I needed a group of people to question about their moods and if they had eaten or not I decided that I could question my friends at summer camp. I was given books to read about foods. I was also given a tape recorder to record my friend’s moods and what they ate for breakfast. And I was given charts to fill in after listing to the tape recorder.

Observations

By asking everyone how they felt after breakfast and after lunch I was able to find the following:

Table One: Who had breakfast

Table Two: How they felt

Table Three: Mood after eating lunch
If someone else were to try my project I would have to say that it is really hard to keep track of everything, so you really have to stay on task. It might be easier if you have a notebook just for this and make tables ahead of time.

Conclusions
I learned that people who had breakfast where tried but happy because breakfast gives you more energy to do things. I learned that after lunch most people were happy but fussy. I think they were fussy because lunch gave them more energy. It also gave people more energy to fight with one another.

Acknowledgements
I want to thank Tracy for helping me get all the materials and getting me started on my project. I want to thank JoAnn for helping me get my graphs together and helping me type out my article. I also want to thank Karen for helping me write down what every ones answers were.

Questions
I wanted to know about the difference between flubber and silly putty. I wanted to know how much each one weighted, which one was the slimiest, what colors you can make them, how each one felt, to find out which one bounced, to see if they roll, what happens when you throw it, and what happens when they are left out. I choose this question because I enjoy playing with these items and wanted to know more about each one.

Materials
To complete my project I needed liquid starch, water, glue, borax and bowls to mix them in. I also needed to have the recipes to know what to mix and how much so that I was sure to get the correct texture. To make the silly putty I mixed together a bottle and a half of glue and three-fourths a cup of liquid starch in a big bowl. I had to stir these two things together then try and shape it with my hands to get silly putty. To make the flubber I had to mix glue and water in one bowl and borax and water in another. Then I mixed the two together, and got flubber.

Observations

<table>
<thead>
<tr>
<th>Question</th>
<th>Silly putty</th>
<th>Flubber</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>237 grams</td>
<td>153 grams</td>
</tr>
<tr>
<td>Slimiest</td>
<td>Slimmest</td>
<td>Slimy</td>
</tr>
<tr>
<td>Colors</td>
<td>Brown, black, purple, blue, red, green, orange, yellow</td>
<td>Brown, black, purple, blue, red, green, orange, yellow</td>
</tr>
</tbody>
</table>

The White Stuff
Jen Age 8
Felt  | Goosy, slimy, drippy, looked like ice cream | Stiff, smooth when rubbed
Bounce | Didn’t bounce | Very bouncy
Roll | Nope | Rolled over about four times
Throw it | Gets stuck to your hand | It would bounce off the floor
When left out | flattened and stuck to table, looks like sprite | Hard outside and was soft on inside

When working on this project people should expect to get dirty, and to wash their hands a lot. Also be careful when leaving it out, cause its hard to get up off of surfaces. So maybe try to put something under it that can be thrown away.

I learned that the silly putty turns hard when left out, and that flubber turns a little soft and hard. I thought that when I left them out that I would come back and find them the same way I left them. So coming back and finding that the silly putty had changed was a big surprise.

Acknowledgements
I would like to thank the camp councilors and Tracy for helping me and teaching me how to make all these things. I would also like to thank Kirstie cause she would always come over and help if I needed an extra hand. Also my cousin Mattie for coming to camp and helping me test how far my flubber and silly putty would roll.

I enjoyed learning about flubber and silly putty. I would like to do this again because it was fun getting dirty and playing with the mixtures.

Trying to make a piano

Ariel Age 9

Question
My original question was how to make a piano.

I chose this question because I thought it would be fun. I thought it might be fun because I didn’t know how pianos could make their sounds. I didn’t know how to make a piano and I thought it might be interesting to try. We looked on the Internet for information about building the piano but couldn’t find any information so I had to try to figure it out myself.

Materials
Toy piano, scow driver, and wire

Observation
I opened the toy piano and I saw: resistors, speaker, wires (red, black, and yellow), and pegs, handle outline. I think that the wire connected the keys when the other side of the wire is connected to the battery pack it makes
a circuit and when you press a key it breaks the circuit and it makes a sound.

It would be helpful to others if they understood what a circuit was and how they work. They might also want to know what resistors are and how they work. It might also be helpful to look at a real piano. This can be done by looking on the Internet at pictures or taking apart a toy piano.

Conclusions
I learned how a piano worked. I learned that resistors are like sockets that help make the circuit in the piano. I was also able to better understand how a circuit works because I got to take one apart and see how it works.

Acknowledgements
I would like to thank Tracy and Joann two of the best councilors.

My one-clawed crayfish.
Anna Hinton: Age 10

Questions

My original question was why is the crayfish body shaped the way it is? I also wanted to know if the crayfish was like the lobster so I wanted to compare the two. I also wanted to know what kind of food the crayfish would eat. I couldn’t answer my questions about the lobster because we couldn’t keep one alive during summer camp. So I had three main questions about crayfish. They were: why and who named crayfish? Why do the crayfish have a specific color? and how do they swim?

I choose this question because I like animals and I like spending time with animals. I wanted to study the crayfish because they are fun to watch and they aren’t as hard to take care of as a dog or cat. The first time I saw a crayfish was at another camp when we went creaking and we caught crayfish with nets, but we had to return them to the water.

Materials-
3 crayfish (no claws, one-claw, two-claws)
Large bowl with water and rocks
Corn
Notebook
Ruler
Books about lobsters

Observations
After the crayfish were in their new homes I took each of the crayfish out and measured them. The crayfish with no claws was 4 cm, - one claw was 5 cm, two- cm. The two - clawed crayfish was much darker red than the other two. The no clawed crayfish was very light almost white in color. That night the no clawed crayfish died. The other two crayfish began to shed their skin and the two- clawed crayfish died in the process. So now I only had one crayfish left.

The next week the one-clawed crayfish grew 1.5 cm so now it is 6.5 cm long. I wanted to know how it swam so we watched for it to get scared and when he did he would pull in his walking legs and use his swimmerets to swim away. I was able
to see the two different kinds of legs by turning him over and looking underneath him.

I wanted to know what kind of food they ate. So we tried three different foods we tried corn, tadpole, and a guppy. He ate one at a time and they were all gone.

What you need to know
They would need more than one crayfish, something like a bowl with water and rocks. They would need books on crayfish and they would need a ruler to measure, and a notebook to write observations. Crayfish don’t live in clarified water, so the water needs to be de-chlorified. The water needs to be room temperature and fresh water. You need a specific amount of water so that they can climb up on the rocks and get air. They should learn about the bodies of the crayfish. They can look in a book about lobsters. Lobsters are the same as crayfish but are bigger. If you turn them over at the same time they would look the same almost. They need to know the difference between a baby lobster and a baby crayfish (teenager crayfish). They need to know how to check if it is a boy or girl. They need to know about the swimmers and how they pull their walking legs in and use their swimmers to swim. They have two different kinds of claws: the pincher claw and the crusher claw. They might need cleaner fish to clean out the cage so the pollution in the water does not hurt the crayfish.

What did you learn?
I learned that you could tell the difference between a boy and girl, lobsters are bigger than crayfish, and they lay their eggs under their tail and swim with the eggs under its tail. They have swimmers under their tails. They use the swimmers to swim with but not their legs. They have little claw things on the bottom of their legs. When they see there pray, they snatch it with the crusher claw and take it up to its mouth which is under its head and they eat it. They have antennae to feel the vibrations in the water. They have eyes on the side of their head. They cannot see behind them, they can only see in front of them. I learned that they are the colors that they are for camouflage to hide from its enemy. They use rocks to hide under also, and they live under rocks. I did not get a chance to look this up, but I think that baby crayfish is bigger than baby lobsters. Baby lobsters are no bigger than a penny when they are born. Crayfish fight for no good reason, just over boys and girls. I learned that if they fight for a long time, they can loose both of their claws. They can grow their claws back.

Acknowledgement
I want to thank Tracy, for teaching me about them. I want to thank Stephanie, for getting them for me. I want to thank Melanie, JoAnn, for believing that I could do it.
Seed growth and salt water
Karen Age 12

My first question was how the amount of salt water would effect the growth of seeds. Truthfully I originally wanted to study atoms and the human body. But unfortunately my lab (science) teacher thought that was too easy and gave me this project.

I chose this question because it was kind of challenging because I didn’t already know the answer unlike the other projects I came up with.

Materials
To set up my experiment I used Zip lock baggies, carrot seeds and, radish seeds. Damp paper towels, salt and water. I had to use a graduated cylinder.

Observations
I wrote down the colors and length of each seed but like every great experiment I came to a problem. In one bag I put to much water. that was bad I drowned my plants. the water could not evaporated because there was to much salt water.

Seeds grow in little salt water but not to little they need salt water but the amount has to be balanced. Also keep the baggies sealed.

I learned water cannot evaporate if there is a larger amount of salt water. And plants can’t grow in a lot of saltwater.

My Flowers
Tabitha Age 5

Questions
I wanted to know how do flowers grow, when do flowers grow, why do flowers grow. I also wanted to find out more about what was inside the flowers. I wanted to find out where the poisonous milk was keep on the inside. I wanted to know if flowers help us with anything, like to get better. I wanted to know all these things about flowers because I see them everyday and think they are pretty. I wanted to try to figure out how and why flowers grew when I’m not around. To also find out if flowers can grow foods that we need.

Just because some things take time to grow it doesn’t mean it won’t eventually grow.

Acknowledgement
I would like to thank my friends JoAnn, Tracy and Stephanie. They have all inspired me they were my muse. I have never met people who care so much about children (their Job).
Observations

Everyday I got a different flower to look at and one to take home. I had paper and markers to draw a picture of what I found inside flowers. To find what was inside each flower I pulled them apart and used toothpicks to tear apart the stem. I was given a ruler to measure the flower stem. I laid the flower next to the yardstick and looked to see how long it was then I put it across the yardstick and found out how wide it was.

I found a bud, after I pulled all the petals off. I also found gooey stuff in the stem that I think is poisonous milk. I also squeezed the stem and water came out. Once I opened the stem it looked like there was two stems inside because I saw lines going up and down it. After I got all the petals off I found a bud. The bud had something to do with us being around, like it wouldn’t grow when we were around. It also had to do with water, cause water makes the flower grow and it wouldn’t give it water when we were around. It also had tons and tons of holes to help hold the petals in. I also saw that the stems had water dripping from them as we were taking them apart.

Conclusions

I learned that flowers do have something to do with us being around. When we are around they don’t grow. I also learned that it is really hard not to poke yourself with the toothpick and that I had to be extra careful when using my toothpick. I learned that not all flowers have poisonous milk, some just have water inside them. I also learned that the bud is what holds the petals on the flower.

Acknowledgements

I would like to thank my camp councilor JoAnn. I would like to thank her because she helped me to learn about flowers. She helped me by giving me toothpicks, and helping me use them so that I didn’t hurt myself. She also helped me to count the petals that I picked off of each flower. I would also like to thank Tracy for buying me the flowers.

THE END

Different Colored Ink

Jane Age 10

Questions

What are the different colors in different makers? What are the different colors of gel pens? I did it before with one red marker, but I wanted to know more colors but in different type of markers and different colored markers. Mostly I used black markers. I also wanted to know the same things about gel pens. But there were only blue, purple, and pink.

Materials

I used permanent markers, water based markers, washable coloring markers (which is the same type of markers I used my first time doing this experiment) and I had to use acetone (nail polish remover.)

Observations

I thought everything would work, but it turned out that the gel pens wouldn’t separate and the regular washable markers only separated in
one color, which was the same real color. Below is a data chart about my results using filter paper and regular sketch paper to compare the results.

<table>
<thead>
<tr>
<th>Color Marker</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red on filter paper #1</td>
<td>Pink, white, and purple</td>
</tr>
<tr>
<td>Blue on filter paper #1</td>
<td>Navy blue, and baby blue</td>
</tr>
<tr>
<td>Black on filter paper #1</td>
<td>Purple and brown</td>
</tr>
<tr>
<td>Black on filter paper #2</td>
<td>Grey and black</td>
</tr>
<tr>
<td>Black on filter paper #3</td>
<td>Purple and blue</td>
</tr>
<tr>
<td>Red on paper #2</td>
<td>Pink</td>
</tr>
<tr>
<td>Blue on paper #1</td>
<td>Navy blue</td>
</tr>
<tr>
<td>Black on paper #3</td>
<td>Purple and brown</td>
</tr>
<tr>
<td>Black on paper #4</td>
<td>Purple and blue</td>
</tr>
<tr>
<td>Green on paper #1</td>
<td>Turquoise</td>
</tr>
<tr>
<td>Red on paper #1</td>
<td>Orange</td>
</tr>
<tr>
<td>Black on paper #1</td>
<td>Grey</td>
</tr>
<tr>
<td>Blue on paper #1</td>
<td>Baby blue and navy blue</td>
</tr>
</tbody>
</table>

Conclusions
From this project I learned that there are different results for different pens. Not all pens use the same kinds of chemicals to make the ink. Some of the pens didn’t work because they had gel ink in them. So in order for this experiment to work you need water based ink pens. The pens that worked the best were the sharpies of any color.

Acknowledgements
I would like to thank Tracy for buying the supplies and my mom for supporting me in my decision. I would like to thank the other teachers that helped, such as JoAnn, Stephanie, and Melanie.

Magnets
Anthony Age 9

Questions
I wanted to know how strong magnets are? Also out of all the different shaped magnets which one was the strongest? I wanted to know more about magnets because I was always into playing with magnets. I really had no clue how strong magnets were.

Materials
I was given different kinds of magnets like bar magnet, circular magnets, square magnets, clip magnets, bingo wand. To test the strength of the magnets I was given plastic paper clips, metal paper clips, metal bingo chips, bolts, nuts, washer, screws, nails, and copper hinges.

Conclusions
I found that big magnets aren’t always better, which proves bigger the better is not always true. I found this out by using a really big bar magnet that I thought would pick up a ton of paper clips, but it only picked up one
or two. Sometimes small magnets can be really powerful. I found this out by using a small circular magnet. I thought that the magnet really wouldn’t pick up much, but it turns out that it was the third best magnet. The best magnet was a small bar magnet. It was able to suck the paper clip from two inches away along a piece of paper. I also ran a test with the bingo wand. I was able to find that the longer and slower you pull it out the more chips it would pick up. Tie a paper clip to the end of a piece of string and tie the other end of the string to the table. Pull the paper clip into the air and put a magnet just above the paper clip and let go of the paper clip and the magnet will keep the paper clip hovering.

I would say to use a variety of magnets. And to just mess around with them and see what kind of test you can come up with on your own to learn about magnets.

I learned that bigger magnets aren’t stronger. I also found that smaller magnets aren’t always weaker. Size with magnets makes no difference in strength. Messing around with the strongest magnets was really fun, and I liked coming up with my own experiments.

Magnets and electricity was a helpful book because it gave me an idea for a test. It helped me to discover seeing if you could move paper clips around the table. The Science book of magnets was gave me the experiment idea of trying to make a paper clip hover.

Acknowledgements
I would like to thank Tracy for pushing me to do more experiments.

Growing Mold
Terry  Age 7

Questions
Why does mold grow? I just wanted to know, I had a question for my dad, what does mold grow on. I knew that mold could grow on houses. My mom told me that. So I wanted to know where else mold could grow.

Materials
Bread slices-wheat and rye
Cheese slices
Cereal cinnamon toast crunch
Lemonade and vinegar
Bowls

First you need to buy the stuff that you need. Then you put the bowls on the table and put the food in it. Then if you have cool aid you put that on it. You leave it sit for a few days and you see what happens. If mold will grow or not. Add your liquid until it covers the food you are trying to grow mold on.

Observations
I observed the bowls on days one, two, six, seven, and nine. In the table is an example of some of my observations that I made of mold.

<table>
<thead>
<tr>
<th>Type of Substance</th>
<th>Day One</th>
<th>Day Six</th>
<th>Day Nine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rye with Lemonade</td>
<td>Push</td>
<td>Push</td>
<td>Red, white green mold</td>
</tr>
<tr>
<td></td>
<td>When</td>
<td>down</td>
<td>all over the</td>
</tr>
<tr>
<td></td>
<td>you</td>
<td>stays</td>
<td></td>
</tr>
<tr>
<td>Treatment</td>
<td>Observation</td>
<td>Conclusion</td>
<td></td>
</tr>
<tr>
<td>--------------------------------</td>
<td>--------------------------------------------------</td>
<td>---------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Wheat with Lemonade</td>
<td>Push down and then it comes back up. So it was still soft. No Mold</td>
<td>The bread was hard underneath.</td>
<td></td>
</tr>
<tr>
<td>Cereal with Lemonade</td>
<td>Cereal was soggy. No mold</td>
<td>Mold was read white and also fuzzy. There looked like there was hair on the mold.</td>
<td></td>
</tr>
<tr>
<td>Cheese with Vinegar</td>
<td>Cheese is still yellow. No Mold</td>
<td>Hard, fuzzy mold. Hair is white, green darker in color.</td>
<td></td>
</tr>
</tbody>
</table>

**Conclusions**

I learned what colors mold can be. They can be white, fuzzy white, green, green with gray, red. Sometimes mold can be hairy. Sometimes the mold feels like marshmallows. It took seven days before I was able to observe any mold growing. After the mold started to grow it got a little bit bigger everyday.

The mold grew better on both breads and the cereal. It didn’t really grow on the cheese, except there was a white spot, but I don’t know what that was. The lemonade or cool aid grew better mold and more of it than the vinegar did.

I would like to do this again. If I did I would change the food in it. I would put pop tarts, still have the rye and wheat bread, and I would have chips like Jordan did. I wouldn’t use vinegar again because it didn’t work. But I might use a pop of some kind.

**Acknowledgements**

JoAnn and Tracy and were helpful with my project. My partner was Jeff B. and he was helpful.

Camp Councilors
Stephanie, JoAnn and Melanie
Individual Structured Interview Questions

The purpose of these instruments are to gage students attitudes towards science, to learn what they know about science and the work of scientists, and finally to learn how they communicate ideas about science at home and in other environments and how they change over the course of this research.

Pre I Wonder Program Structured Interview Questions:

Introduction to the interview task- I am about to ask you to answer a few questions about yourself and your ideas about science. I would like to tape record your answers so that I am able to remember the things that you told me after we are finished. There are no right or wrong answers to these questions. Your answers to these questions will not affect your participation in the summer camp in any way. You are allowed to choose to tell me not to record your answers now or at any time during our time together. Is it okay if I tape record our conversation?

I also want you to know that if there are questions that you don’t understand you can ask me to repeat the question or explain what the question means. Do you understand this? Also, if you do not wish to answer any of the questions all you have to do is say PASS and we will move on to another question. Can you explain to me what I just told you?

Good let’s begin. The first question is:

1. Tell me about your science class in school, what kinds of things do you learn about or do?
2. What do you think science is?
3. What do you think scientists do at work? At home?
4. What types of science things do you talk about with your family or friends?
5. Can you be a scientist? Why or why not?
6. If you wanted to share an idea or thought about science with a friend or family member how would you do this?
7. How do you think scientist share their ideas about science with: Friends, Family, and Other scientists.
8. Is science important? Why?
Middle of the I Wonder Process Open-Ended Interview Questions

Introduction to the interview task- Just like at the beginning of summer camp, I am about to ask you to answer a few questions about yourself and your ideas about science. I would like to tape record your answers so that I am able to remember the things that you told me after we are finished. There are no right or wrong answers to these questions. Your answers to these questions will not affect your participation in the summer camp in any way. You are allowed to choose to tell me not to record your answers now or at any time during our time together. Is it okay if I tape record our conversation?

I also want you to know that if there are questions that you don’t understand you can ask me to repeat the question or explain what the question means. If you do not wish to answer any of the questions all you have to do is say PASS and we will move on to another question. Could you explain to me what I just told you?

1. How are the activities we do here at summer camp like those you do in school?
2. Which summer camp activities have you enjoyed the most? Why?
3. Describe the science project you are planning and researching.
4. Have you shared your science project with family or friends? How about any of the other activities you have been involved in.
5. How would you describe the science project you are working on to someone who was not a part of our summer group?
6. What ideas have you learned from other groups or students by talking with them and learning about their project ideas?
7. How does this experience compare to what you think scientists so at work?
8. Is it important to work alone, in a small group, or large group when doing science experiments? Why?
9. When we work on activities in the mornings that usually make up your group?
10. Do you think this group works well together? Why or Why not?
11. What kind of roles do you take in that group (leader, follower)?
12. Do you feel like you do your fair share of the work?
13. Do you remember who you were paired with for the flashing ball activity? It seemed that this didn’t work well for students. How did it work for you? Why?
14. Is it important to learn to share your ideas with others who are not your friends?
Post I Wonder Program Structured Interview Questions:

Introduction to the interview task- Just like at the beginning of summer camp, I am about to ask you to answer a few questions about your self and your ideas about science. I would like to tape record your answers so that I am able to remember the things that you told me after we are finished. There are no right or wrong answers to these questions. Your answers to these questions will not affect your participation in the summer camp in any way. You are allowed to choose to tell me not to record your answers now or at any time during our time together. Is it okay if I tape record our conversation?

I also want you to know that if there are questions that you don’t understand you can ask me to repeat the question or explain what the question means. Do you understand this? Also, if you do not wish to answer any of the questions all you have to do is say PASS and we will move on to another question. Could you explain to me what I just told you?

1. Tell me about what you liked best or least about summer camp?
2. What did you learn this summer that you never knew before?
3. What did you learn this summer that you thought you knew before, but you learned more about?
4. What do you think science is after being in camp?
5. Do you feel differently about learning science after this summer?
6. What did you learn about science as a result of your I Wonder?
7. What do you think scientists do at work? At home?
8. What types of science things do you talk about with your family?
9. Can you be a scientist? Why or why not?
10. If you wanted to share an idea or thought about science with a friend or family member how would you do this?
11. How do you think scientist share their ideas about science with: Friends, Family and Other scientists?
12. Is science important? Why?
13. Is it important that science be shared with others, peers, other scientists, family and friends? Why or why not?
APPENDIX C
PARENT LETTER AND CONSENT FORMS
Dear Parent/Guardian,

You have requested information about the summer camp held from July 8, 2002 - August 16, 2002. As a summer camp participant your son or daughter will be involved in many social and educational experiences. For example have the opportunity to do arts and crafts, play sports, as well as educational experiences such as drama, reading and science. As a part of the educational activities with your consent your son or daughter may be part of educational research. We would like to take the time to describe in detail just one of the research activities your son or daughter might participate in as a part of the summer camp offered this summer at the Newark Branch Campus of The Ohio State University. The name of the program is I Wonder. Students will have the opportunity to participate in a group scientific investigation as well as complete a scientific investigation that they are interested in or curious about. The students will meet three times per week for a little over an hour where they will work with a partner or small group to ask scientific questions, plan scientific investigations, design methods, and collect data. At the end of the investigations students will be asked to write a summary article of their findings which will become part of the camp I Wonder Journal presented to all the students on the last day!

During the course of this research program, students will participate in pretests and post tests on science skills, individual and group interviews about the program, as well as record their findings and thoughts in a student journal. We are interested in learning about how students communicate their new science knowledge to one another. In order to do this the students will be audio and video taped during the sessions. No audio or videotape will be publicly viewed; the tapes will only be used by the researcher to collect information and will be erased and destroyed at the end of the research. Your students’ logbook will also be collected, but will be returned to you with information about what the study learned if you are interested.

Please feel free to call the Project Director Paul Vellom or Tracy Huziak at any time should you have any questions. Your child will be allowed to participate in the summer camp and this activity even if you do not consent to her participation in the research project.

We hope that you would like your son or daughter to participate in the I Wonder Program and develop a greater interest in science. If you agree to allow your son or daughter to participate in I Wonder research project please sign the consent form on the following page. If you have additional questions please feel free to contact the Project Director, Paul Vellom, 614-292-8056.

Yours sincerely,

Dr. R. Paul Vellom       Tracy Huziak
Project Director          Graduate Student
CONSENT FOR PARTICIPATION IN SOCIAL AND BEHAVIORAL RESEARCH

Protocol title: The Study of Scientific Literacy, Verbal and Written Communication, Used During Open- Inquiry Projects

Protocol number: _____

Principal Investigator: R. Paul Vellom

I consent to my participation in (or my child’s participation in) research being conducted by R. Paul Vellom of The Ohio State University and his/her assistants and associates.

The investigator(s) has explained the purpose of the study, the procedures that will be followed, and the amount of time it will take. I understand the possible benefits, if any, of my participation (and/or my child’s participation).

I know that I can (and/or my child can) choose not to participate without penalty to me (and/or my child). If I agree to participate, I can (and/or my child can) withdraw from the study at any time, and there will be no penalty.

I consent to the use of audiotapes and/or videotapes. I understand how the tapes will be used for this study.

I have had a chance to ask questions and to obtain answers to my questions. I can contact the investigators at Vellom.1@osu.edu or 614-292-8056. If I have questions about my rights as a research participant, I can call the Office of Research Risks Protection at (614) 688-4792.

I have read this form or I have had it read to me. I sign it freely and voluntarily. A copy has been given to me.

Print the name of the participant:

______________________________________________________

Date: _____________________________________________________________________________

Signed: ____________________________________________________________________________

(Participant)

Signed: ____________________________________________________________________________

(Principal Investigator or his/her authorized representative)

Signed: ____________________________________________________________________________

(Person authorized to consent for participant, if required)

Witness: __________________________________________________________________________

(When required)
APPENDIX D

I WONDER ARTICLE QUESTIONS TO BE ANSWERED
I Wonder Journal Article Write-up Questions-

What title do you think would fit your project?

What were your original question or questions?

Why did you choose this question?

What materials did you use in your set-up of your experiment?

What kind of observations did you make?

What would someone else need to know to do your experiment again?

What did you learn from your project that you did not know before?

What reference materials did you use?

Who was helpful to you while working on your project (students, camp councilors, ect?)

Any thing else you want to add?
APPENDIX E
FOCUS GROUP QUESTIONS
Focus Group Interview Questions

The purpose of these instruments is to lead a large group discussion about the student projects. I am interested to learn if students discuss their ideas or their research differently as a result of being in a larger group setting or not. These questions will give students an opportunity to share their ideas verbally if they wish to do so.

Introduction to the Focus Group Interview Task: I have asked all of you to come here today to ask you a few questions about what you think about your project so far. I would also like to give you an opportunity to share what has gone well so far and things that you are having trouble with in your individual projects. I would like to hear from as many of you as possible, so if you would please raise your hand when you would like to contribute so that I can call on you individually that would be great. You are not required to answer any of these questions if you are not comfortable answering them on tape. Can anyone explain to me what I just told you?

1. Would someone please share with the class the questions they are going to try to solve as a part of their I Wonder Project.
2. Would someone please explain any problems or concerns they may have. (Allow other students to brainstorm solutions).
3. How is this process of discussion with peers similar to what “real” scientists do?

If students are not answering the above questions, I may try to get them started by referring to the topic board and asking questions like the following before returning to the above questions.

Jimmy I noticed you have changed your topic. Would you like to explain why? Sue I don’t see a question listed, do you have ideas you would like to share with the class? Jim and Sue are working together, how have your questions changed?
Second Focus Group Discussion Questions

Introduction to the Focus Group Interview Task: Just like before I have asked all of you to come here today to ask you all a few questions about what you think about this project so far. I would also like to give you an opportunity to share what has gone well so far and things that you are having trouble with in your individual projects. I would like to hear from as many of you as possible, so if you would please raise your hand when you would like to contribute so that I can call on you individually that would be great. You are not required to answer any of these questions if you are not comfortable answering them on tape. Can anyone explain to me what I just told you?

1. Would someone like to share their progress so far?
2. Would someone please explain any problems, or concerns they are experiencing. (Allow other students to brainstorm solutions).
3. Based on your current data collection are your original hypotheses correct and why?
4. What have you learned so far about the process that scientists use to research a problem?
5. How can you use this method in your own life outside of school?
APPENDIX F
PRE/POST TEST AND RUBRIC
Sample Task Cards for Science Process Skills

Note to Interviewer: Please read the following statement to each student and fill in the appropriate blanks with as much detail as possible.

For each of the following tasks you can read the cards to the students, or the students can read the directions out loud to you. You may answer any procedural questions the students may have, but you should not answer or give hints to the answers for the students.

Read aloud to the students:

Would you please tell me your name and spell it for me? __________________
What grade are you going to be in this year in school? ____________________
How old are you today? _____________________

You are about to complete several science activities. There are many different ways to complete each task and it is up to you to decide how to do what the directions ask you to do. In some cases the directions will ask you to write or draw something. These activities will be video taped so that I can remember what you did step-by-step. If you would prefer not to be video taped or want me to turn off the camera at any time all you have to do is ask, do you understand? Can you explain what I just told you?

Task Card One: Observation

(Materials: One stuffed animal, one plant or other living organism)

What can you tell me about the properties that each of these items have. List or state as much information as you can about each object. You may touch or hold either item.

List observations here:

Rubric– 6 possible points

0- lists no characteristics or properties of each
1- lists a few properties, but makes no comparisons
2- lists properties and makes at least two comparisons
3- lists properties and makes more than three comparisons

0- lists no properties
1- uses only qualitative or quantitative properties
2- uses mainly qualitative or quantitative properties
3- uses a variety of qualitative and quantitative properties.
Task Card Two: Sorting
(Materials, common household items)

Design a way to organize all of the objects here in front of you in a way that would make sense to another student. You should have at least three groups.

Interviewer: List the number of groups and the items in each group here:

Rubric- Five possible points
0- only one group or not able to sort
1- only able to sort into two groups
2- sorted into two groups
3- sorted into three groups- with at least three items per group
4- sorted into four groups- with at least three items per group
5- sorted into five groups- with at least three items per group

Interviewer: Ask the student if they can think of another way to group the objects? Describe that method here:

Rubric- three possible points
0- no attempt made
1- attempt made without success
2- one suggestion or idea change made
3- two or more suggestions made

Task Card Three: Measurement
(Materials: meter stick, graduated cylinders, and balances)

How would you determine how tall this chair is? Give me an accurate measurement.

Interviewer: Describe the process which the students use to measure, i.e. what tools and were they accurate? Record the measurement students give you.

Rubric- Five possible points
1 point for correctly naming the meter stick
2 points for correctly using the meter stick, placing the zero at the floor and measuring to the top of the chair.
1 point for an accurate measurement of 102 cm
1 point for using correct measurements- centimeters
How would you determine how much volume this rock has? Give me an accurate measurement.

Interviewer: Describe the process which the students used to measure, i.e. what tools and were they accurate? Record the measurement students give you.

*Rubric- Five points possible*

1 point for correctly naming the triple beam balance
2 points for correctly using the balance, starting with the hundreds and moving to the ones.
1 point for an accurate measurement of 212 g.
1 point for using correct measurements- grams

**Task Card Four: Estimation**
(Materials: One large plastic container sealed, filled with jellybeans or like item)

- How many jellybeans do you think are in this jar, make estimation for me.
- How could you determine if your estimation was close without actually counting the jellybeans?

Interviewer: Record students estimation here:

Record students answer to how they would more accurately determine the number here:

*Rubric- Three points possible*

1 point for stating an estimation

0- no stated method for more accurate estimations
1- student made a suggestion, but it would not be possible to carry out.
2- Student suggested a reasonable method, or mathematical calculation for estimation.

**Task Card Five: Predictions**
(Materials: Five days of consecutive weather maps)

- Given the weather maps from the past five days what do you think the weather in this area will be like tomorrow. Explain your reasons for this prediction.

Interviewer: Record the prediction and explanation here:

*Rubric- Three points possible*

0- no prediction
1- prediction made but no reason given
2- prediction made but the reason given was not based on evidence
3- prediction made and reason given was based on evidence
Task Card Six: Communication
(Materials: Magic sand)

How would you describe the experiment you just witnessed to your best friend? Explain here, you may use a drawing if you would like to.

Rubric- Four points possible
0- no answer given
1- drawing or written description, without an explanation
2- drawing with explanation/labeling or written explanation with brief explanation
3- written explanation with evidence
4- written explanation with evidence and drawing to support ideas