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PRESERVICE AND PRACTICING TEACHER SCIENCE INQUIRY PROJECTS:

AN ANALYSIS OF THEIR UNDERSTANDING OF THE INQUIRY PROCESS

An Abstract of a Dissertation

Submitted

in Partial Fulfillment

of the Requirements for the Degree

Doctor of Education

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ABSTRACT

Student conducted inquiry is an essential component of the Next Generation Science Standards and considered to be a core goal of teaching science methods. Teachers need to understand what student inquiry entails, to be able to successfully conduct their own inquiry investigations, and to understand this process well so as to guide original student inquiry investigations. Some suggest that, as a result of No Child Left Behind legislation, an entire generation of students have missed out on inquiry-based elementary science instruction. Research indicates that many preservice teachers find it difficult to bridge knowledge of subject matter with pedagogy – making use of content knowledge in ways that help all students learn. Many are quite unfamiliar with authentic forms of inquiry, having only experienced confirmatory lab activities while in school. Additionally, preservice teachers often find it difficult to understand how scientific arguments are constructed, transformed into written reports, and published for a wider, authentic audience.

Scientific inquiry is a process of finding answers to questions based upon observation and investigation. Student-centered scientific inquiry is much more than just doing prescribed experiments or letting students “run wild.” There is a process that must be understood and followed by the teacher. A lack of inquiry understanding by the teacher may lead to incomplete student learning. The purpose of this study was to describe preservice and practicing teachers’ understanding of the scientific inquiry process. These projects were analyzed to: (a) determine the successes and problems students encountered in their presented inquiry projects; (b) to compare the projects made

by preservice teachers to those of practicing teachers to determine the strengths, weaknesses, and the participant's general understandings of the inquiry process between these two groups; and (c) to recommend improvement to this sort of project for greater student growth in science inquiry understanding.

The study used mixed methods: descriptive content analysis design and descriptive statistics and analyzed data from undergraduate and graduate students projects completed in *ELEMECML 3161 Teaching Elementary School Science* course and *ELEMECML 6242 Analysis and Improvement of Science Instruction in Elementary Schools* from 2012-2015. The projects were analyzed using an instrument that was designed by the investigator to reflect recommendations from the professional literature. The instrument included six categories of the main phases of the inquiry process: Orientation, Making Observations, Gathering Evidence, Considering New Evidence, Conclusion, and Communication. The data analysis used descriptive statistics, inter-rater reliability, and qualitative analysis. The researcher classified and analyzed 141 projects.

The 141 projects that were evaluated had a mean score of 74.7%, based on the points earned on the inquiry project evaluation instrument. This average indicates that these groups of teachers do not fully understand the many intricacies of the scientific inquiry process. The scores within these 141 projects ranged 99.2% to 40.8%. When analyzing specific categories of the scientific inquiry process, the category that scored highest on average was Gathers Evidence, with a mean score of 83.0% of the possible points earned. The category with the lowest means scores was Considers New Evidence.,

with 43.0% of the points earned. Five of the six inquiry categories showed strong positive correlations between category scores and the final overall score for the project, indicating that proficiency in each of the categories of inquiry is important to overall success in the process.

Practicing teachers consistently scored higher than preservice teachers, though not always statistically significantly different. When compared between the two groups of teachers, the category of Orientation had p value of 0.034, Makes Observations had a value of 0.007, and Communication showed a significant difference of 0.007. The total score comparison yielded a p value of 0.021. The other three inquiry categories did not show significant differences, indicating that practicing teachers were not significantly better at demonstrating their understanding of the inquiry process than preservice teachers.

Eight themes emerged when describing positive indicators. The most vital process of scientific inquiry was the synthesis of multiple information sources and among the different phases of inquiry. The results guide suggestions for better use of scientific inquiry related to the use of direct, concrete instruction of each phase of the inquiry process, along with concentrated effort to model and emphasize synthesis within the entire inquiry process.

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DEDICATION

This dissertation is dedicated to my family, who gave me the strength and desire to complete this. I hope the work is important and influential, impacting my children and grandchildren. I also wish this work to be evidence to my children that anything is possible with hard work and dedication.



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CHAPTER 1 INTRODUCTION

In 2001, federal legislation was passed to re-authorize the Elementary and Secondary Education Act which is commonly known as No Child Left Behind (Bush, 2001). The mandate of No Child Left Behind was to ensure that 100% of students were proficient in math and reading. The pressure to move all students to prescribed levels of proficiency forced many school districts and teachers to drastically narrow the curriculum they delivered, as well as streamline their pedagogical delivery methods (Jennings & Retner, 2006). With the heavy emphasis on math and reading, time allocated to science was severely reduced (Griffith & Scharman, 2008). Students were exposed to fewer scientific concepts in smaller allotments of time (Marx & Harris, 2006). This rarely allowed for student-centered, hands-on science experiences. There was very little time or emphasis placed on learning science through inquiry-based methods. To develop scientific practices such as asking questions, analyzing data, and constructing explanations, learners require opportunities to experience inquiry at many levels, with the goal of eventually conducting higher levels of inquiry (Whitworth, Maeng, & Bell, 2013). Students growing up in the age of No Child Left Behind have missed out on early, formative experiences in science (Marx & Harris, 2006).

Today's science teachers seem to be receiving conflicting messages, one message calls them to address the learning needs of all students by scrutinizing their instruction through standardized testing, while also receiving the calls to teach science through inquiry-based methods that have been shown to enhance learning for all students

(Aydeniz & Southerland, 2012). Oftentimes, teachers decide to follow the message of standardized testing because of its public accountability (Aydeniz, 2007).

Despite this apparent departure from hands-on, experience based science in many schools, student conducted inquiry is an essential component of the Next Generation Science Standards (NGSS) and considered to be a core goal of teaching science methods (NGSS Lead States, 2013). Teachers need to understand what science inquiry entails to successfully conduct their own inquiry investigations, and to master the process to then guide students in original inquiry investigations (Cook & Buck, 2013). Research has shown that school science inquiry has the potential to enhance students' higher order learning skills, such as metacognition and argumentation (Dori & Sasson, 2008; Kaberman & Dori, 2009). In fact, research indicates that hands-on, inquiry-based science instruction helps students develop positive attitudes and increases their motivation to learn science (Hofstein & Mamlok-Naaman, 2007). Furthermore, Kenyon, Schwarz, and Hug (2008) indicated growing evidence that supports student engagement in inquiry-based, modeling activities that help students learn content effectively and build subject matter expertise.

Au (2007) proposed that, as a result of No Child Left Behind legislation, an entire generation of students have missed out on inquiry-based elementary science instruction. Without having experienced inquiry-based instruction, it is questionable whether today's preservice teachers have the appropriate background and understanding of the inquiry process to effectively implement it as a pedagogical strategy in their future classrooms. It's important that undergraduate, preservice teachers have positive inquiry experiences

in science methods class so that they are prepared to teach science to elementary students (McLoughlin, Findlayson, & Brady, 2014; Yoon, Joung, & Kim, 2012).

Statement of the Problem

Ball (2000) wrote that most preservice teachers find it difficult to bridge knowledge of subject matter with pedagogy – or the making use of content knowledge in ways that help all students learn. Many preservice teachers are quite unfamiliar with authentic forms of inquiry, having only experienced confirmatory lab activities while in school (Kang, Bianchini, & Kelly, 2013). Furthermore, preservice teachers often find it difficult to understand how scientific arguments are constructed, transformed into written reports, and published for a wider, authentic audience (Zemba-Saul, Munford, Crawford, Friedrichsen, & Land, 2002). If today's nascent teachers entering the field of education do not comprehend the process of authentic inquiry, it may be very difficult, or impossible, for them to effectively implement inquiry as a pedagogical strategy in their classroom. An analysis of preservice teacher understanding of the scientific inquiry process and its pedagogical implementation would be used to inform teacher education practices.

Need for Study

Student conducted inquiry is an essential component of the Next Generation Science Standards (NGSS) and considered to be a core goal (NGSS Lead States, 2013) of teaching science methods. Teachers need to understand what science inquiry entails, to be able to successfully conduct their own inquiry investigations, and to understand this process well so they can guide student inquiry investigations (Cook & Buck, 2013). In

light of the aforementioned lack of elementary science experiences of many preservice and practicing teachers, in part, because of No Child Left Behind legislation, researchers have found that teachers have not fully applied inquiry-based science in their classrooms, often opting for more traditional methods of teacher-directed instruction (Asay & Orgill, 2010). If a young teacher attempts to implement inquiry in their classrooms, but do so in a manner that is not consistent with the true spirit of inquiry, the inexperienced teacher often devolves into long fact finding exercises (Hutto, 2012). Soprano and Yang (2013) stated that inquiry instruction cannot be effective without first experiencing representative inquiry-based approaches. Without formal experience in inquiry-based teaching and learning in teacher preparation programs, practicing teachers typically omit inquiry-based teaching or rely on professional development programs to gain understanding of inquiry-based science (Lebak & Tinsley, 2010). Preservice teachers need to understand the nature of inquiry and the thinking process of hypothesis-making and justification (Yoon et al., 2012).

Therefore, exploring what today's preservice teachers understand of the inquiry process is vitally important. This knowledge can help lead to better planning and implementation of preservice teacher education programs, as well as professional development for teachers already in the field.

Purpose of the Study

This investigation analyzed preservice teacher inquiry projects and practicing teacher inquiry projects to better understand how well these groups of educators have internalized and have the ability to use the inquiry process. These projects were analyzed

to: (a) determine the successes and problems students encountered in their presented inquiry projects; (b) to compare the projects made by preservice teachers to those of practicing teachers to determine the strengths, weaknesses, and the participant's general understandings of the inquiry process between these two groups; and (c) to recommend improvement to this sort of project for greater student growth in science inquiry understanding.

Researcher's Personal Interest in the Topic

I have served as an elementary school teacher for the past 14 years. Twelve of those years were spent in the regular classroom and the last two were spent providing K-6 Talented and Gifted services. My philosophy and approach to education have evolved over the years as my varied experiences have shaped my views on education. However, there is one view that has remained steadfast through those years, and has continued to be strengthened by my practice in the field and by my post-graduate education at the University of Northern Iowa. This view is the belief in the absolute importance of providing learners with authentic, inquiry-based experiences while learning science. Since my undergraduate days, I have had a great interest in science education. As I was educated in the Elementary Basic Science minor program, I was instilled with the vision of what science teaching and learning should encompass: students working together, or independently, to learn problem solving skills through scientific issues by asking their own questions, conducting tests of theories, and determining answers that satisfy their understanding of the content. Student inquiry allows students to not only learn about science, but to really *do* science, as a scientist would.

With the belief also comes the recognition that for students to learn through authentic inquiry, the teachers working with them must be able to effectively implement the process. Inquiry-based science is much more than just executing prescribed experiments or letting students “run wild” in the science classroom. There is a definite process that must be understood and followed by the teacher. A lack of teacher understanding of inquiry may result in learning that is not as effective as it could be. Therefore, it interests me greatly to investigate the demonstrated comprehension of a selected group of preservice and practicing educators regarding the inquiry process as determined through an analysis of their inquiry projects. Can preservice teachers conduct inquiry themselves? If not, what weaknesses in their inquiry process can be deciphered? I hope that the findings of this study help to guide preservice education to prepare new teachers in the best possible way, especially when looking at training new teachers to effectively implement inquiry-based approaches in their future classrooms.

Research Questions

The following were research questions to guide the study:

1. How well do preservice and practicing teachers follow accepted inquiry procedures?
 - a. What was included in the projects of preservice and practicing teachers that exhibited understanding of the inquiry process?
 - b. What was missing from the projects that indicate lack of full understanding of the accepted inquiry process?

2. Is a practicing teacher's demonstrated understanding of the science inquiry process after obtaining experience in the classroom different from that of a preservice teacher?

Chapter 2 focuses on the literature related to the topic. The literature review features research on the understanding of the inquiry process, support for implementing the inquiry process in the classroom, and teachers and the inquiry process. Chapter 3 proposes the design of the study. Chapter 4 provides a summary and interpretation of the results. Chapter 5 highlights discussions, practical implications, and ideas for future research.

CHAPTER 2

LITERATURE REVIEW

The following review of the professional literature will assist in understanding the existing body of knowledge as the study sets out to understand the following questions:

1. How well do preservice and practicing teachers follow accepted inquiry procedures?
 - a. What was included in the projects of preservice and practicing teachers that exhibited understanding of the inquiry process?
 - b. What was missing from the projects that indicate lack of full understanding of the accepted inquiry process?
2. Is a practicing teacher's demonstrated understanding of the science inquiry process after obtaining experience in the classroom different from that of a preservice teacher?

To better understand the important concepts surrounding this study, the following review of literature will focus on three main topics. First, the literature review will highlight components of the inquiry process through a historical perspective. Second, the literature review will examine the support for implementing the inquiry process in the classroom. Discussion will highlight how inquiry has become part of the national standards for science, demonstrating that the use of inquiry is not only desired practice, but also a necessity to meet standards.

Third, the literature review will present a discussion on teachers and the inquiry process. Preservice and practicing teacher projects are being analyzed for their understanding of the scientific inquiry process, premised on the idea that a better understanding of the process facilitates better use of inquiry in the classroom. In addition to support for inquiry-based science instruction, this review of literature will also examine misunderstandings of the inquiry process used in classrooms worldwide.

Understanding the Inquiry Process

Scientific inquiry is a process of finding answers to questions based upon observation and investigation. It involves forming, testing, and revising beliefs (Stalnaker, 1984). Inquiry can be seen as a way for an investigator to explore authentic questions that have real meaning to the investigator (Hill, Stremmel, & Fu, 2005). Basic processes involved in scientific inquiry are making initial observations, creating researchable questions, formulating predictions, planning procedures to undertake investigation, collecting and organizing data, sharing ideas, revising ideas, and, eventually reaching consensus on answers to the original questions (Leonard & Penick, 2009). Inquiry can be defined in a practical and accessible way as “an active learning process in which students answer research questions through data analysis” (Bell, Smetana, & Binns, 2005, p. 33).

Historical Perspective of the Inquiry Process

There is a long line of inquiry in which humans have tried to figure things out. Since the very beginning, humans formulated myths to explain phenomena that were occurring in the natural world. This complex set of thinking abilities, which helped early

humans gather food and escape danger, can be described as a form of inquiry (The Center for Science, Mathematics, and Engineering Education, 2000). In more recent history, within the past 6,000 to 7,000 years, some humans continued to use their capacity for inquiry to explain things other than basic subsistence, such as the causes for seasons, the movement of celestial objects, or the origins of organisms. Stories were concocted that explained what was happening. The earliest humans reasoned as best they could comprehend their world. They saw the lightning in the sky (a “problem”) and then used all their available knowledge and resources to find a solution (gods are angry or fighting).

As civilization progressed, so did the ideas and solutions. For example, the Greek civilization of ancient Greece’s Golden Age, 500-300 B. C., took huge leaps forward in the area of figuring things out. Their ideas and explanations became more complex and the ways in which conclusions could be drawn became more varied. Many famous philosophers and learners originated from this civilization, such as Socrates, Plato, and Aristotle. Ancient Greece was far from the earliest, nor the only civilization making strides in figuring out the world. Natural human inquiry was found in all corners of the natural world as civilizations rose and fell.

As history progressed, so did the human need to understand and make sense of the world. Later philosophers and scientists included such names as Descartes, Spinoza, Locke, Bacon, Copernicus, Galileo, and Newton. Later, Hume, Berkeley, and Kant provided ideas and explanations of their own. The common thread through the history of humanity is that there has always been a desire to determine how the world works.

However, the way that one goes about determining these underlying mechanisms of inquiry may vary immensely.

Georg Wilhelm Friedrich Hegel, a philosopher of the Romantic Movement of the late 18th century into the early 19th century, worked to develop a philosophy to be used as a method for understanding the progress of history. Hegel states that history is like a river and we are standing at one point in that river. A thought can be correct from where we stand in that river of time. At the same time, we are influenced by what has come before us, upstream, and we can influence what comes after us, downstream. But, at that place and time, humans must do all they can to understand how things work for that place and time. They need to use resources, both external and internal, that existed prior to this point in time, and then must interpret them in an effort to solve problems in the immediate situation.

The inclusion of inquiry into K-12 science curriculum was recommended by John Dewey in the early twentieth century (1910, 1938). Dewey felt too much emphasis was placed on scientific fact without enough emphasis on science for thinking and attitude of mind (Barrow, 2006). Dewey encouraged K-12 teachers to use inquiry as a teaching strategy when the scientific method was too rigid. He promoted students being actively involved and the teacher acting as a facilitator or guide (Barrow, 2006). Dewey (1938) advised that students' experiences should be related to the problems they study. He writes that in order for an experience to be educative, students must be active learners while searching for solutions to problems with which they are presented.

Another great push for science inquiry came with the launch of Sputnik I on October 4, 1957 by the Soviet Union. This event caused the officials in the United States to question the quality of the science teachers, methods, and pedagogy used in schools at the time (Barrow, 2006). After this event, the rationale for inquiry as an approach to teaching science was increasingly accepted (Center for Science, Mathematics, and Engineering Education, 2000). Thinking like a scientist who would use an inquiry process to solve problems became a more logical approach to the teaching of science content (DeBoer, 1991). Schwab (1966) argued science principles should be viewed as conceptual structures that are revised as a result of new evidence. His views recommended that teachers present science as inquiry and that students use inquiry to learn science subject matter (Center for Science, Mathematics, and Engineering Education, 2000). The work of Dewey and Schwab, amongst many others, along with current events of the time, prompted the development of numerous new curriculum materials and professional development opportunities. Many of these endeavors were funded by the National Science Foundation with the commitment to involve students in the doing of science, rather than just being told or only reading about a particular concept or idea (Center for Science, Mathematics, and Engineering Education, 2000).

These efforts were effective in raising awareness of the use of inquiry in the K-12 classroom, but use of the curriculum materials created or inquiry approaches promoted was not as widespread as initially anticipated (Harms & Yager, 1981; Weiss, 1978). Several research studies were undertaken to discover why inquiry was still not as widespread a teaching approach as was hoped. Welch, Klopfer, Aikenhead, and Robinson

(1981) prepared a report called Project Synthesis which outlined the current state of science education at the time, the late 1970's. The report indicated that many teachers did not use inquiry, citing reasons such as limited teacher preparation, lack of time, limited availability of appropriate materials, and difficulty to teach as major reasons (Welch et al., 1981). A decade later, Eltinge and Roberts (1993) identified three main reasons that teachers avoid inquiry, those being official state documents that emphasize content, easier access to content-oriented materials, and the emphasis in textbooks of science as an existing body of knowledge. With the knowledge that inquiry was a powerful way to teach science, yet the understanding that inquiry was not as widespread as desired, the development of national standards emphasizing inquiry began. Twenty years have now passed since this study on teachers' use of the inquiry process. Therefore, this current study will become an important analysis of where today's teachers, who are preparing to enter the field, stand in their preparedness to use inquiry in the classroom.

The Inquiry Process

Scientific inquiry is a quest for understanding the natural world based upon humans' innate curiosity and desire to figure things out. Scientific inquiry is not the only form of inquiry that exists. Other forms of knowledge possess their own forms of inquiry and developments to gain new knowledge. For the sake of this paper, the word inquiry refers to the specific process of scientific inquiry.

The inquiry process is the heart of the inquiry-based instruction. Inquiry-based instruction is an approach to teaching and learning methodology that engages students in the process of figuring things out, allows the learner to do the hard work of solving the

problem, and centers around the research process (Donham, Bishop, Kuhlthau, & Oberg, 2001). Students work to solve problems, but also ask their own questions and manage information to create their own understandings. Inquiry-based instruction is a student-centered, and aims to both support students in developing a deep understanding of scientific knowledge, facts, and concepts and to enhance students' abilities to reason and think autonomously. Learners work to identify big questions and use their own initiative and problem solving skills to find relevant answers. Another goal of this type of instruction is to reveal science and engineering fields to the learner for further consideration as future career areas (McLoughlin et al., 2014).

Inquiry is a complex activity involving several actions which are often cyclical in nature. Scientific inquiry involves making observations, posing questions, examining existing information on the subject, planning investigations, examining what is already know by observed evidence, using the correct tools to gather, analyze, and interpret data, proposing answers or explanations, and communicating results. Additionally, those involved in inquiry must be able to identify assumptions, use critical and logical thinking, and also consider alternative explanations.

In a work published for the National Science Teachers Association, Windschitl (2008) wrote that the overall goal of any scientific inquiry experience was to develop defensible explanations of the way the natural world works. Windschitl (2008) proposed four main steps in the process of scientific inquiry. These steps included (a) organizing what is known and what investigators would like to know, (b) generating a hypothesis or model, (c) seeking evidence to test the hypothesis or model, and (d) constructing an

argument that defends the conclusions and inferences proposed. Windschitl (2008) goes further to propose that though there are four basic steps in authentic inquiry, the process should be organic, as well as cyclical. Student investigators must often revisit previous steps and revise thoughts as new evidence emerges.

Pedaste et al. (2015, p. 54) ascertained that the basic inquiry process consists of five main components: *orientation*, *conceptualization*, *investigation*, *conclusion* and *discussion*. They set out to clarify the definition of the inquiry process to make it more accessible and understandable to instructional designers and teachers by undertaking a meta-analysis of 32 articles describing inquiry cycles. Two of the five main components can be further delineated. Within the component of *conceptualization*, there are the actions of questioning and hypothesis generation. These two actions are still directly linked with the *orientation* phase. Within the component of *investigation*, researchers (students) will be found exploring, experimenting, and interpreting data. At all times, within all components of the inquiry process, Pedaste and colleagues (2015) assure that communication and reflection are constantly occurring, and are essential pieces to the success of the investigation.

As a part of an inquiry framework developed to guide teaching and learning using inquiry, the Center for Science, Mathematics, and Engineering Education (2000) described five essential features of classroom inquiry. These features included (a) the learner engages in scientifically oriented questions, (b) the learner gives priority to evidence in responding to questions, (c) the learner formulates explanations from evidence, (d) the learner connects explanations to scientific knowledge, and (e) the

learner communicates and justifies explanations. At the highest levels of student-directed inquiry, learners nurtured under these essential features will be posing their own questions, designing methods for collecting data, then collecting it, examining other related resources to identify links, and forming reasonable and logical arguments to communicate explanations.

In this dissertation, the assigned project completed by both the undergraduate and graduate students drew heavily on ideas presented by the Center for Science, Mathematics, and Engineering Education (2000). This Center determined that the process of inquiry includes several steps. These steps include:

- Making observations;
- Exhibiting curiosity, defining questions;
- Gathering evidence using technology and mathematics;
- Consulting previous research;
- Publishing explanations based upon evidence;
- Considering new evidence;
- Adding to the previous explanation; and
- Using explanation to inform public policy.

These activities were described through the lens of professional science, and then compared to the process of inquiry that might be found in a science classroom, mimicking quite closely what a scientist might do. These classroom inquiry practices (Center for Science, Mathematics, and Engineering Education, 2000) include:

- Making observations;
- Exhibiting curiosity and defining questions from current knowledge;
- Proposing preliminary explanations or hypotheses;
- Planning and conducting simple investigations;
- Gathering evidence from observation;
- Explanation derived from evidence;
- Considering new evidence;
- Communicating explanations; and
- Testing explanations.

There are interesting parallels between the procedures of inquiry in the field of professional science and classroom science. Inquiry can take many forms, being highly structured investigations or free-ranging explorations of unexplained phenomena.

However, the Center for Science, Mathematics, and Engineering (2000) advocates that all inquiry follows the same basic pattern of discovery. This pattern will guide the analysis of inquiry projects for the current study.

Table 1

*Parallels Between Professional Scientific Inquiry and Classroom Scientific Inquiry
(Center for Science, Mathematics, and Engineering, 2000)*

Professional Scientific Inquiry	Classroom Scientific Inquiry
Making observations	Making observations
Exhibiting curiosity, defining questions	Exhibiting curiosity
Gathering evidence	Proposing hypotheses
Consulting previous research	Conducting simple investigation
Publishing explanations	Gathering evidence
Considering new evidence	Explanation from evidence
Adding to the previous explanation	Considering new evidence
Using explanation to inform policy	Communicating explanations
	Testing explanations

Support for Implementing the Inquiry Process in the Classroom

National science standards have included support for student inquiry for quite some time when the American Association for the Advancement of Science (AAS) first released the Benchmarks for Science Literacy in 1993 (AAS, 1993). Three years later, the National Science Education Standards demonstrated something even more fundamental than defining a way of teaching or learning. These standards emphasized the idea of inquiry encompassing not only an ability to engage in inquiry, but an understanding of inquiry and how inquiry results in scientific knowledge (National Research Council, 1996).

National Standards

The developers of the National Science Education Standards understood the historical perspective of inquiry on which to base the creation a set of national standards (National Research Council, 1996). Studies of teaching and learning in science classrooms indicated that most teachers were still using traditional methods of instruction where students were mastering disconnected facts instead of forming a greater understanding of concepts or using problem solving and critical thinking skills (Center for Science, Mathematics, and Engineering Education, 2000). However, in the classrooms that were using inquiry-based approaches, students were found to be making observations, manipulating materials, and conducting investigations, all the while developing cognitive abilities such as critical thinking and reasoning, while still learning science content (Center for Science, Mathematics, and Engineering Education, 2000).

Many educational policy doctrines have advocated for inquiry-based science education in recent years, including publications of the National Research Council (2011). Many state level curriculum standards have now come to include inquiry. For example, the Iowa Core Curriculum (2009) explicitly states in its introduction:

The Iowa Core Curriculum for Science emphasizes student inquiry. The depth of understanding required of our students is not possible with lectures, reading, cookbook labs, and plug-and-chug problem solving. Students must be actively investigating: designing experiments, observing, questioning, exploring, making and testing hypotheses, making and comparing predictions, evaluating data, and communicating and defending conclusions. *A district's science curriculum cannot align to the Iowa Core Curriculum for Science without including inquiry as a guaranteed and viable, testable component in every science course* (p.2, emphasis added).

The National Research Council's most recent framework for K-12 science education emphasizes the need for students to actively engage in scientific practices to deepen understanding of core ideas (Keller & Pearson, 2012). Among the many recommendations set forth were eight essential practices that should be included in quality science and engineering practices. These eight practices were investigated by the current study and include: (a) asking questions and defining problems; (b) developing and using models; (c) planning and carrying out investigations; (d) analyzing and interpreting data; (e) using mathematics, information and computer technology, and computational thinking; (f) constructing explanations and designing solutions; (g) engaging in argument from evidence; and (h) obtaining, evaluating, and communicating information (National Research Council, 2011).

The National Research Council has long advocated for inquiry-based science instruction, defining it as: "the diverse ways in which scientists study the natural world and propose explanations based on evidence derived from their work" (National Research Council, 1996, p.23). This approach, "rooted in constructivist thought, seeks to create opportunities for learners to engage in science, gaining in-depth understanding, and building on their previous ideas" (Meyer & Crawford, 2011, p. 529). Reforms aim to move science education away from just learning about science to actually doing science through inquiry in an active classroom setting. In inquiry science, students are doing the thinking and, eventually, the learning, while asking their own questions to guide that learning (Meyer & Crawford, 2011). The National Science Education Standards state,

“Learning science is something that students do, not something that is done to them”
(National Research Council, 1996, p. 2).

The Next Generation Science Standards (NGSS) are the latest set of science standards that emphasize the use of student inquiry in the teaching and learning of science content. The NGSS are benchmarked science standards that were initially released in 2013, with the goal of better preparing students for collegiate and professional involvement in science (Pruitt, 2014). These standards present performance expectations that stress deep understandings of specific disciplinary core ideas. Designed with the Framework for K-12 Science Education in mind, the standards were written as a way to translate the Framework into student expectations (NGSS Lead States, 2013; Pruitt, 2014). The standards are categorized into three main science categories, physical science, life science, and earth and space science. More specifics are found within each category, along with a structure for cross-cutting concepts, disciplinary core ideas, and science and engineering practices. Categories are also divided by grade level expectations.

Reiser (2013) wrote that teachers and administrators must recognize the NGSS calls for a shift away from teaching facts, to students constructing explanations of phenomena, which is the goal of inquiry-based instruction. The NGSS work to use science and engineering practices together with core ideas and cross-cutting concepts to help students build a rich network of connected ideas that serve as conceptual tools for explaining phenomena, solving problems, and making decisions, as well as acquire new ideas (Krajcik, Codere, Dahsah, Bayer, & Mun, 2014).

School Science and Inquiry

Increased accountability in America's classrooms has pressed teachers to find time to instruct their students in all subject areas. Effective teachers seek to employ effective and motivating teaching methods for all subjects, including science. High quality science education is an international priority according to the National Science Board (2007). Globally, governments have recognized the contributions that a full, rich science education can provide for its citizens (Minner, Levy, & Century, 2010). An important component of student-centered science education is inquiry.

Studies have shown school science inquiry has the potential of enhancing students' higher order learning skills, such as metacognition and argumentation (Dori & Sasson, 2008; Kaberman & Dori, 2009). Evidence indicates hands-on, inquiry-based science instruction helps students develop positive attitudes and increases their motivation to learn science (Hofstein & Mamlok-Naaman, 2007). Furthermore, the body of evidence is growing that suggests engaging students in inquiry-based, modeling activities can help students learn content effectively and build subject matter expertise (Kenyon et al., 2008).

Donham et al., (2001) wrote that inquiry-based learning is important for the simple reason that it is the way that people learn in real life. Learning continues to occur as long as one continues to wonder, ask questions, and inquire. These researchers say,

For students to go through school learning only how to answer the questions that teachers ask but not learning how to generate their own questions and develop strategies for answering them fails to prepare them for real life. We know that children come to school full of wonder and questions, but traditional schools quickly turn off that sense of wonder and question-asking and turn children into answer-seekers. (p. vii)

Along with the impetus for policy reform has come a number of studies that demonstrate the positive effects of inquiry-based science teaching and learning (McNeill & Pimentel, 2009; Wu & Hsieh, 2006). Inquiry-based science instruction has been found to be effective with students from varied backgrounds and academic abilities. A study by Meyer and Crawford (2011) indicated that the use of inquiry-based activities, when coupled with explicit scientific guidance in the nature of science, afforded greater opportunities for students of racially and ethnically underrepresented backgrounds to better understand scientific concepts. McCarthy (2005) focused on middle school behaviorally and emotionally disabled students, and reported overall results that indicated students in the hands-on instructional program performed significantly better than the students in the textbook –focused condition. Internationally, Areepattamannil (2012) reported that inquiry-based science in Qatar had a positive effect on achievement, as well as interest in science.

Taylor et al. (2012) conducted a study using Akkus, Gunel, and Hand's (2007) Scientific Writing Heuristic approach for teaching science, a form of inquiry that emphasizes the use of strategic writing exercises following both teacher and student frameworks to enhance understanding in science laboratory experiences and found that students with disabilities have the potential to be effective at increasing achievement of students with disabilities on the Iowa Test of Basic Skills assessment. They state, "Inquiry-based instruction focuses on big ideas versus rote memorization of facts, which helps students to retain information they learn more easily. Focusing on core concepts

can encourage students to extend their learning beyond traditional science lessons and instruction” (Taylor et al., 2012, p. 28).

Despite the positive effects that numerous studies have demonstrated in support of inquiry in the science classroom, there is still some caution that must be taken when promoting and implementing this process. Kuhn (1989) challenged the idea of metaphor of a child acting as an adult, professional scientist. She presented evidence that the thinking processes of children were quite different from those of adults, especially professional scientists. Because of this, Kuhn (1989) contends that one cannot fully give a young student full and unstructured reign over their meaning making. Unlike a professional scientist, a young child in a science classroom conducting an inquiry-based investigation is likely to be content with a simple, local interpretation and ignore discrepant evidence. One could argue that this happens because thinking is a difficult task and that the brain is not very good at doing it (Willingham, 2009). Willingham (2009) wrote, “People are naturally, curious, but we are not naturally good thinkers; unless the cognitive conditions are right, we will avoid thinking.” (p. 2)

Deters (2005), analyzed the methods of 571 chemistry classrooms across the country and reported that some students do report a negative view of inquiry. When reasons were given, the two main ideas that emerged were that some students did not like that more effort and thinking are required, and some students actually fear being in control of their learning and thinking. This result could be linked to Willingham’s (2009) assertions that thinking takes so much effort that humans would rather avoid it.

Inquiry is all about thinking, though many may only see the hands-on aspects of the teaching approach. However, there is much that must occur cognitively for an inquiry-based investigation to be successful. Those facilitating the inquiry investigations must understand this fact so that they can directly teach students how to think within the inquiry process. With this in mind, one cannot ignore studies such as Minner et al. (2010) whose research conducted from 1984 to 2002 centered on the effects of inquiry-based instruction on science learning. They found clear and positive trends that favored inquiry-based approaches. These positive results emphasize that active thinking and drawing conclusions from data was particularly effective in enhancing and improving science learning (Minner et al., 2010). This further illustrates the need to conduct a study that analyzes just how well present and future teachers really understand the complicated process of inquiry so that they too can stimulate active, critical thinking in their students, even when that thinking is hard, and perhaps a little unnatural.

Teachers and the Inquiry Process

To teach, one needs to possess knowledge. Understanding of the inquiry process can be described as a special type of knowledge that is required for a teacher to successfully teach science. Shulman wrote prolifically about types of teacher knowledge. Shulman (1986) proposed that there are several different categories of knowledge that a teacher must be able to grasp. He mentions three main categories of knowledge: content knowledge, pedagogical content knowledge, and curricular knowledge. Content knowledge refers to the organization and body of facts and concepts related to the subject being taught. Content knowledge has a lot to do with the actual understanding of the

teacher. Shulman (1986) says that one must go beyond simply knowing facts to an understanding of the entire structure of the subject matter. This structure comes from definitions of accepted research and scholarly theory. Beyond this, not only do teachers need to understand those accepted structures of organization, they must also be aware of alternate organizations of that knowledge that may warrant introduction to students. “Teachers must not only be capable of defining for students the accepted truths in a domain. They must also be able to explain why a particular proposition is deemed warranted, why it is worth knowing, and how it relates to other propositions, both within the discipline and without, both in theory and in practice” (Shulman, 1986, p. 6).

Pedagogical content knowledge goes beyond just knowing the subject matter.

This type of knowledge allows the teacher to understand how to best teach a certain topic.

Shulman (1986) says:

Within the category of pedagogical content knowledge I include, for most regularly taught topics in one’s subject area, the most useful forms of representations of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations – in a word, the ways of representing and formulating the subject that make it comprehensible to others (p. 7).

Pedagogical content knowledge assumes that the teacher knows that different subject matter cannot all be taught the same way. In this way, Shulman attests that teaching is domain specific. Teaching surface area is different from teaching students to make inferences in reading, which is again different from teaching how to use scientific models. Not only is the subject matter different, the way a teacher goes about the process of instruction should also be different. The expert teacher must first of all have an understanding of the various subject matters and pedagogical strategies, but they must

also have the ability to read a situation and understand when to utilize the various strategies. This ability is pedagogical content knowledge.

Curricular knowledge is the type of knowledge teachers have that allows them to know where to get materials and other curricular aids. Knowing there are a wide variety of curricular aids to assist in instruction will allow the teacher to be fully prepared to address the varied needs of their students, as determined by the teacher's pedagogical content knowledge (Shulman, 1986).

Teachers' content knowledge is related to the science teaching strategies that they use (Windschitl, 2009). Teachers with stronger content knowledge are more likely to teach in ways that help students construct knowledge, pose appropriate questions, alternative explanations, and propose additional inquiries (Alonzo, 2002; Ledermann, 1999; Roehrig & Luft, 2004). Inquiry teaching also requires teachers to have specific knowledge of how to support students in developing researchable questions, planning an investigation, collecting and interpreting data, and presenting results (Gess-Newsome & Ledermann, 2001; Shulman, 1986). Windschitl, Thompson, and Braaten (2009) showed that specific forms of reasoning with content knowledge are critical to reform-based, inquiry teaching. Windschitl (2009) proposed that because the context of 21st Century skills depends so heavily upon students' engagement with complex problems, teachers can only organize high-quality curricular challenges if they have a deep and well integrated understanding of content and the practices of science, including inquiry, themselves.

Shulman (1987) described the complicated process of teacher development thus:

Their [teachers'] development from students to teachers, from a state of expertise as learners through a novitiate as teachers exposes and highlights the complex bodies of knowledge and skill needed to function effectively as a teacher. The result is that error, success, and refinement – in a word, teacher-knowledge growth – are seen in high profile and in slow motion. The neophyte's stumble becomes the scholar's window. (p. 4)

Shulman's (1987) described the complexity of good teaching, but also portrayed the difficulty of developing pedagogical content knowledge that allows for smooth inquiry-based lessons. Furthermore, because teaching is so complex, Shulman (1987) hinted at the fact that teacher development is a slow, sometimes painful process.

Windschitl (2009) wrote that research into undergraduate preparation indicates that the content knowledge gained as a preservice teacher is often superficial and not well integrated. Many preservice teachers hold serious alternative conceptions about science content, similar to those held by their students (Anderson, Sheldon, & Dubay, 1990; Songer & Mintzes, 1994). The findings of numerous research studies indicate that both elementary and secondary teachers are lacking deep and connected conceptual understanding of the subject matter they are supposed to teach, as well as lacking deep understanding of the scientific processes that led to existing knowledge (Windschitl, 2009). In fact, Lemberger, Hewson, and Park (1999) and Roth (1999) confirmed that preservice teachers lack basic knowledge of methodology and rarely think in terms of scientific theory or process. Later, studies described teachers' understandings of authentic inquiry practices placed little or no value on crucial tenets of inquiry teaching, such as

model development, explanation, or argument (Windschitl, 2004; Windschitl & Thompson, 2006).

Misunderstandings of the Inquiry Process

Hutto (2012) warned against the distortion of the scientific inquiry process. He believed that the process originally designed to help explain natural phenomena using inference has been diluted to little more than fact finding exercises. Though Hutto (2012) understands that fact finding is an integral piece of scientific inquiry, he contends that much inquiry stops here and is passed off as real science, when, in fact, nothing new comes of the investigation, other than a synopsis of what others have already found. Hutto (2012) says, “Not only are we driving children away from science through our failure to describe scientific inquiry as a simple, yet creative process, but we are also graduating students who have never experienced or fully understood science as a way of seeking knowledge” (p. 708).

Power (2012) found students who held the belief that all the information that one would need for a scientific investigation can be gathered in one single search activity. Through potentially ill-conceived inquiry experiences, students had come to the conclusion that inquiry is basically fact finding, including such actions as exploring websites, organizing information, or just printing out all the information that they find. Power (2012) suggested that teachers plan future inquiry experiences that include a higher level of cognitive challenge and provide greater opportunities for students to develop proficiency in inquiry skills. Windschitl (2009) reported that research done with preservice science teachers indicated that most participants described inquiry as

collecting and analyzing data, but not connecting this data to underlying explanation or theory. Further, participants indicated that previous school-related research experiences influenced what they believed could be incorporated into inquiry, many of whom were held up by a simplistic view of the scientific method, which constrained the procedures they felt could be used in investigations (Windschitl, 2009).

Though inquiry-based instruction policy documents and curriculum materials are constantly being developed and implemented as a way to improve science education, research indicates that actual implementation of science inquiry in school is problematic (Abd-El-Khalik et al., 2004; Ireland, Watters, Brownlee, & Lupton, 2012). Other research indicates that teachers have not fully applied inquiry-based science in their classrooms, often opting for more traditional methods of teacher-directed instruction (Asay & Orgill, 2010). Additionally, there are few research studies that have explicitly examined teachers' instructional practices in inquiry-based classrooms (McNeill & Krajcik, 2008). Therefore, there is a need for more explicit, concrete examples of inquiry-based classrooms in order to better understand how inquiry science is enacted in ways that promote student learning (Haug, 2014).

Preservice Teachers and the Inquiry Process

Preservice teachers need to experience the inquiry process during their school years, or at least, within their teacher education program (Yoon et al., 2012). Soprano and Yang (2013) stated that inquiry instruction cannot be effective without first experiencing inquiry-based approaches. Without formal experience in inquiry-based teaching and learning in teacher preparation programs, practicing teachers either omit inquiry-based

teaching or rely on professional development programs to gain understanding of inquiry-based science (Lebak & Tinsley, 2010). Preservice teachers need to understand the nature of inquiry and the thinking process of hypothesis-making and justification (Yoon et al., 2012). Teachers entering the field need to learn about inquiry instruction by engaging in social discourse, where they learn from their peers and more experienced members of the culture or group, and by also actually engaging collaboratively in inquiry (Syer, Chichekian, Shore, & Aulls, 2013).

Shulman (1998) discussed the important roles that post-secondary play in developing teachers:

I have tried to help students see how one traverses the gap between Piaget's developmental theory and what to teach on Monday morning or between Vygotsky's zones of proximal development and pedagogical potential of group work. We who have tried to educate future professionals understand the challenge that is created when one's starting point for an education in learned profession is immersion in vast bodies of knowledge. We prepare professionals in universities because we make the strong claim that these are learned professions and that academic knowledge is essential to their profession (p. 517).

Undergraduate preparation is essential for success later in an individual's teaching career because much of the initial knowledge base for teaching comes from this source. Content knowledge grows during the undergraduate years, initial understandings of various pedagogies are introduced, and introductions to curricular options are made. In an earlier paper he wrote, "An emphasis on pedagogical content knowledge would permeate the teacher preparation curriculum" (Shulman, 1987, p. 20).

Preservice teachers face several challenges as they enter the field expecting to teach in an inquiry-based manner. Ball (2000) found that most preservice teachers he

studied find it difficult to bridge knowledge of subject matter with pedagogy – making use of content knowledge in ways that help all students learn. Many are quite unfamiliar with authentic forms of inquiry, having only experienced confirmatory lab activities in while in school (Kang et al., 2013). Additionally, preservice teachers often find it difficult understanding how scientific arguments are constructed, transformed into written reports, and published for a wider, authentic audience (Zemal-Saul et al., 2002).

Feiman-Nemser and Buchanan (1989) asserted that “prospective teachers area not blank slates; they come to their professional studies with ideas and commitments that are likely to affect their learning to teach... thus, learning outcomes in teacher education are a function of both what programs offer and what people bring” (p. 368). This points to the idea that student teachers likely enter teacher education program with traditional and transmission oriented views of teaching and learning (Syer et al., 2013).

Syer et al. (2013) examined if university students’ exposure to inquiry experiences differed in their conceptualizations of inquiry demands and instruction. They concluded that preservice teachers entering teacher education programs hold a somewhat naïve or incomplete conceptualization of the inquiry approach. Further, they found that conceptualizations students hold about inquiry pedagogy can influence the importance they place on various tasks involved in carrying out and inquiry-based curriculum. They emphasized the need for learners to demonstrate how to do the following:

- a) develop and solve problems using data, b) construct one’s own knowledge, c) learn about the values of learner reflection on the inquiry process, d) redefine the purpose of asking learners questions, and e) be taught how to pose questions to learners that do not merely test for mastery of teacher-directed content. (p. 534)

Windschitl (2003) conducted a study that found that preservice teachers who had experienced authentic inquiry prior to full time teaching, showed more willingness and proper execution of inquiry teaching. Prior to experience with authentic inquiry, Windschitl described his preservice, teachers as students who “were unable to articulate a coherent model of inquiry” (p.118). Within his study, Windschitl (2003) proposed that preservice teachers who experienced authentic inquiry experiences during preparation showed more willingness to implement inquiry-based methods on their practicum experiences. Therefore, Windschitl (2003) advised that it is critical to provide some authentic inquiry experiences to preservice teachers within their science methods courses, or at least within some professional development. He said that prospective teachers “must become familiar not only with criteria that define suitable inquiry questions (through authentic inquiry process) but they must have access to strategies for helping young learners understand and use the criteria” in classroom situations (p. 139-140).

In a study that explored preservice teachers’ difficulties in science inquiry teaching, Yoon et al. (2012) found that preservice teachers encountered some difficulties and problematic moments in their science inquiry teaching. When defining these difficulties, they highlighted three problems “during the lesson” and three problems within the minds of the preservice teachers. The difficulties encountered within the lesson were described as: (a) developing children’s own ideas and curiosity, (b) guiding children in designing experiments appropriate for their hypotheses, and (c) scaffolding children’s data interpretation and discussion. The difficulties found within the minds of the

preservice teachers were: (a) tension between guided and open inquiry, (b) incomplete understanding of hypothesis, and (c) lack of confidence in science content knowledge.

In a study of graduate students being trained in using the inquiry process Moseley and Ramsey (2008) found that there were many misconceptions of what inquiry really was. Students had incomplete definitions of the process of inquiry, often describing it as unfocused learning and included mostly lists of actions. Lacking in these definitions was the idea that discovering and exploring had a specific target, as well as the lack of understanding of the importance of student generated, yet focused questions. Additionally, students in this course initially overlooked the value of building connections within the process of inquiry. Moseley and Ramsey (2008) did find that perceptions and definitions of the inquiry process improved after specific reflection regarding inquiry. Their findings suggest that reflecting on the inquiry process can help “teachers to broaden their understandings of inquiry in four distinct areas: a) inquiry is a coherent process consisting of particular actions, b) inquiry exists on a continuum, c) the goal of inquiry is science conceptual development, d) Inquiry provides a concept for building connections between those engaged in inquiry, science and other content areas, and science and life” (p. 54).

Summary and Conclusion

Inquiry is the method that an investigator uses to explore authentic and meaningful questions that have a real meaning to that investigator (Hill et al., 2005). This review of literature has demonstrated that there is a long line of inquiry that humans have been engaged in for thousands of years. Inquiry has been a natural part of human history

for as long human have been trying to figure things out (The Center for Science, Mathematics, and Engineering Education, 2000). Advocacy for inquiry-based science instruction has increased over the past century to the point that national standards are calling for the inclusion of inquiry in quality science instruction. The National Research Council (1996, 2011) has long advocated for inquiry, while state level science standards such as the Iowa Core Curriculum (2009) have also mandated that a district's science curriculum cannot align with standards unless inquiry is an integral part of pedagogy. Most recently, the Next Generation Science Standards (2013) have continued the trend to advocate that science cannot be effectively taught without the use of authentic inquiry. These standards all signal a shift away from teaching merely facts to classrooms where students are constructing explanations of phenomena (Reiser, 2013).

National standards are not the only arena in which inquiry-based instruction is advocated. Numerous researchers have promoted the idea that infusing inquiry into the science curriculum has positive and lasting effects. Studies have shown that school science inquiry has great potential to increase higher order thinking skills (Dori & Sasson, 2008). Donham et al. (2001) argued that inquiry-based learning is important for the simple reason that it's the way that people learn in real life. History, standards, and researchers all propose that inquiry is an effective and authentic way to learn. Therefore, this form of science teaching should be utilized in classrooms worldwide. However, it is very important that teachers understand the process that is inquiry.

In order to implement inquiry in the science classroom, teachers must understand how this process works. Scholars such as Windschitl (2008), Pedaste et al. (2015), and

the Center for Science, Mathematics and Engineering Education (2000) have detailed what that process looks like, pulling heavily from the real world of science and applying it to the science classroom. Though there are slight variations with various reports, most agree that the scientific inquiry process is comprised of making observations, defining questions from current knowledge, planning and conducting investigations, gathering evidence from observations, considering new evidence, creating explanations based upon all evidence, testing explanations, and communicating explanations to a larger audience. The analysis instrument, described in Chapter 3, pulled heavily from these three sources. Table 2 compares the inquiry process as described by each author.

Table 2

The Scientific Inquiry Process as Described by Selected Sources

Center for Science, Mathematics, and Engineering	Pedaste et al., 2015	Windschitl, 2008
Exhibits Curiosity; defines question from current understanding	Orientation	Setting broad parameters for the investigation
Propose preliminary explanations or hypotheses	Questioning	Organizing what we know and what we'd like to know
Plans and conducts simple investigation	Hypothesis Generation	Generating testable hypotheses
Gathers evidence from observation	Experimentation	Seeking evidence through multiple forms of observation
Explains based on evidence	Explanation	Constructing an argument based on evidence, but also considers other possible explanations
Considers other explanations	Data Interpretation	Develop a defensible explanation of the way the natural world works
Communicates explanations Tests explanation	Conclusion	

In getting closer to the heart of this study, it is recognized that a teachers' content knowledge and pedagogical content knowledge is essential in defining how they can or will help students construct knowledge, pose questions, or propose explanations (Shulman, 1986; Windschitl, 2009). Inquiry teaching requires teachers to have a specific knowledge of how to support students in developing questions, planning investigations,

collecting data, and presenting results (Gess-Newsome & Lederman, 2001; Shulman, 1986; Roehrig & Luft, 2004). The unfortunate reality is that misunderstanding of the process of inquiry leads to incorrect or incomplete use in the classroom, particularly the belief that everything one might need for a scientific investigation could be gathered in one single search activity (Power, 2012) or belief that nothing new comes of an investigation other than a synopsis of what others have already found (Hutto, 2012).

Some research indicates that teachers are not fully applying inquiry in their classrooms, opting for traditional and teacher-directed methods, often despite district, state, or nationwide calls for student-centered inquiry (Assay & Orgill, 2010). While considering this, Haug (2014) insists there is a need for more explicit, concrete examples of inquiry-based classrooms in order to better understand how inquiry science is enacted in ways that promote student learning. Without formal experience in inquiry-based teaching and learning, whether as a K-12 student or undergraduate student, practicing teachers may omit inquiry teaching from their repertoire (Lebak & Tinsley, 2010). Experience in inquiry brings better understanding of the process (Windschitl, 2003). However, without those experiences misconceptions about what inquiry really is often form (Mosley & Ramsey, 2008). If preservice teachers are to effectively implement inquiry in their classrooms, they need to understand the process. If teacher education programs want to effectively meet the needs of their preservice teachers, they need to understand what those preservice teachers know, and don't know, about the process of inquiry. This study aims to help answer the question of what preservice teachers

understand, and lack for understanding, of the inquiry process. The next chapter outlines the methodology for undergoing such a study.

CHAPTER 3 METHODOLOGY

The purpose of this study was to describe preservice and practicing teachers' understanding of the scientific inquiry process. This chapter describes the procedures and methods used in this study. It includes reviewing the research questions, research design, participants, survey instrument, data collection procedures, and methods of data analysis.

Research Questions

Student conducted inquiry is an essential component of the Next Generation Science Standards and considered to be a core goal of teaching science methods. Teachers need to understand what inquiry entails, to be able to successfully conduct their own inquiry investigations, and to understand this process well so as to guide original student inquiry investigations. Therefore, it is important that teachers understand the inquiry process.

The central question that framed this research was "Do preservice and practicing teachers understand the inquiry process?" The intent of the study was to determine the successes and problems teacher education students encountered in their presented inquiry projects by comparing the projects made by preservice teachers to those of practicing teachers to determine the strengths, weaknesses, and teacher's general understandings of the inquiry process between these two groups. The analysis resulted in recommended improvements to this sort of post-secondary project for greater student growth in science inquiry understanding. The following research questions answered the one central question for this study. The research questions include:

1. How well do preservice and practicing teachers follow accepted inquiry procedures?
 - a. What information was included in the projects that exhibited preservice and practicing understanding of the inquiry process?
 - b. What was missing from, or incorrect within, the projects that indicate lack of full understanding of the accepted inquiry process?
2. Is a practicing teacher's demonstrated understanding of the science inquiry process after obtaining experience in the classroom different from that of a preservice teacher?

Research Design

The study used mixed methods: descriptive content analysis design and descriptive statistics. A content analysis study provides an intensive, holistic, and in-depth focused on the study of existing documents (Best & Kahn, 2003). The descriptive content analysis examines how well both preservice and practicing teachers understand the process of inquiry, as expressed by a project completed as a culminating assignment in a science methods class. According to Best and Kahn (2003):

a content analysis is concerned with the explanation of the status of some phenomenon at a particular time or its development over a period of time. It serves a useful purpose in adding knowledge to fields of inquiry and in explaining certain social events (p. 248).

There are many applications in educational research for content analysis. When this type of research is applied to the current study, the most relevant uses include an effort to describe prevailing practices or conditions, the discovery of the relative

importance of certain topics or problems, and the quest to explain possible causal factors related to some outcome, action, or event (Bell & Kahn, 2003).

These culminating projects were existing data. Johnson and Christensen (2008) describe existing data as the following:

data that were collected, recorded, or left behind at an earlier time, usually by a different person and often for an entirely different purpose than the current research purpose at hand. (p. 217)

The data were collected over the course of five years by a science methods professor as files for posting and sharing among the then-current students in different sections of an online component of the blended course. Using descriptive analysis the data was assessed for the quality of the participants' understanding of the inquiry process. The use of this set of existing data in this dissertation research project was approved by the University of Northern Iowa Internal Review Board Human Subjects Committee in March, 2015.

Gay, Mills, and Airasian (2011) assert that examining records is an effective form of observational, descriptive research. They indicated that researchers may use any number of artifacts in their investigations, including documents, archives, journals, maps, videos, audio recordings, or other physical artifacts. This type of observational research emphasizes understanding the natural environment as lived by the participant, without altering or manipulating it (Gay et al., 2011).

Study Sample and Data Collection

Participants

The study included undergraduate and graduate students who were enrolled at the University of Northern Iowa. All students who completed *ELEMECML 3161 Teaching Elementary School Science* course and *ELEMECML 6242 Analysis and Improvement of Science Instruction in Elementary Schools* from 2012-2015 completed projects and were analyzed for data collection.

The undergraduate course was titled *Teaching Elementary School Science*. Preservice teachers who completed the course were either juniors or seniors and included 117 participants. The graduate course was titled *Analysis and Improvement of Science Instruction in Elementary Schools*. Practicing teachers who completed the course had between zero and five years in the profession. The practicing teachers consisted of 52 students from a variety of Iowa communities. Both courses were taught by the same instructor.

Learning Goals of the Science Education Course

Both of these courses covered elementary school science, as well as effective and efficient pedagogy to help children learn both science content and process. The courses worked under the following four premises describing elementary school science:

1. Learners should experience the richness and excitement of knowing about and understanding the world.
2. Learners should use appropriate scientific processes and principles in making personal decisions.

3. Learners should be able to engage intelligently in public discourse and debate about matters of scientific and technological concern.
4. Learners can increase economic productivity through the use of knowledge, understanding, and skills of the scientifically literate person in their careers.

These two courses recognized the emphasis of scientific literacy found within the latest versions of national science standards. To these ends, the course focused on the idea that science is for all children, understanding that students will learn via different paths and to different depths, but remembering that all students should be given multiple opportunities to learn and participate in science. Learners in both these courses were instructed that learning science is an active process that involves observing, describing, classifying objects and events, asking questions, collecting data, constructing and testing explanations, and communicating ideas to others.

The courses also espoused the idea that school science reflects the intellectual and cultural traditions that characterize the practice of contemporary science, meaning that students should learn the nature of science, how scientists work, and the role of science in everyday life. Finally, emphasis was placed on the idea that improving science education is part of systemic education reform, specifically that all of the school reform movements call for authentic, real-world tasks, active learning, and more higher-order thinking skills. To accomplish this, longer-term projects should be incorporated into the curriculum instead of short, unconnected activities (National Research Council, 2011).

Through all of this, the courses were based on the idea that in order for learners to develop an appropriate scientific literacy, three parts of science have to be addressed:

attitudes, skills, and content knowledge. The attitudes needed to be scientifically literate included both emotional and intellectual attitudes. Both of these attitudes were stressed to be positive, open, and curious. The course also discussed the important of process skills as ways of thinking that are used to solve scientific problems. These included to types of process skills, basic and integrated. Basic skills were described as things such as observing, classifying, communication, measuring, and predicting. Integrated process skills include identifying and controlling variables, experimenting, graphing, interpreting, modeling, and investigating. The third part of scientific literacy taught within this course was science content knowledge. This part is obviously very necessary for scientific literacy, but the courses taught that this should not be the sole focus of science instruction or it may lead to memorization and poor attitudes about science, at the expense of attitudes and skills. The course based all of this learning around the idea of student inquiry in the classroom.

The Natural World Inquiry Project

Students in both courses were tasked with conducting an authentic inquiry project detailing an inquiry investigation into identifying clouds, trees, wildflowers, birds or similar natural specimens or an inquiry into what might be observed and inferred by studying nature-related phenomena such as holes in trees, squirrels, icicles, shadows, or frost patterns that they could adapt at some point to use within their own classrooms. The goal of the assignment was twofold. First, participants would learn scientific content and increase their knowledge of the natural environment of Iowa. Second, the assignment would prompt future, or practicing, teachers to conduct their own inquiry investigation,

allowing these teachers to actually experience the process of authentic scientific inquiry. Ultimately, it was hoped that this assignment would help teachers become more pedagogically prepared to teach in an inquiry-based manner, as well as increase content knowledge regarding the subject they chose to investigate. PowerPoint presentations were completed as a culminating project for the science methods courses, showcasing the process they went through, as well as detailing the new content knowledge gained.

The project required participants to engage in an inquiry project that they might be able to someday use in their own classroom. They were first instructed to choose a topic that had something to do with the natural environment of Iowa. From there, participants had several requirements to address. Participants began by recording observations that sparked interest in this inquiry project, basically describing why they became curious about the topic. They then went deeper by recording two or three questions that they hoped to answer by conducting this investigation. Next, participants were asked to write out their plan for the investigation, including such details as tools to be used or what information resources they hope to access. If they planned to talk to experts, they would mention that here as well. Within this plan, there was a requirement to examine books and other sources of existing information, including the Internet. Important vocabulary was to then be introduced, along with accepted definitions.

From this point, participants recorded observational data, as outlined in their study plan, and interpreted conclusions for the project. After this section, participants were asked to consider future investigations into this same topic, reviewing what is already known and what is still to be investigated. They needed to consider alternative

viewpoints to the conclusion they had drawn, and then discuss other ideas yet to be investigated, formulating at least two new ideas or questions that are related to the project in some way. All throughout the project, participants were to document their work with photographic evidence, both original, or sourced and cited from somewhere else.

At the time of the Inquiry assignment/project, called the Natural World Inquiry Project all students were provided with two example inquiry projects made by the instructor as illustrated PowerPoint presentations, a PowerPoint template showing the basic parts of the assignment for students to write over and adapt; and a detailed scoring rubric listing the criteria for grading. The instructor of the course posted Natural World Inquiry Project on the University's online learning platform, eLearning, for students to view and to respond to classmates via a discussion board regarding strengths and ions. This work was then kept on file by the instructor with the intention of reflecting on the quality of the work for course improvement.

Description of Instrument

The instrument used for this project analysis was designed by the investigator and based upon the inquiry information students were given prior to the assignment completion. The instrument was guided by *Inquiry and the National Science Education Standards: A Guide for Teaching and Learning* (Center for Science, Mathematics, and Engineering Education, 2000). This text was the resource preservice and practicing teachers had when completing the assignment. The basic process of inquiry project was introduced within a vignette in Chapter 1, and then expanded upon throughout the book.

All categories found within the instrument are referenced within Pedaste et al. (2015) and Windschitl (2008).

The instrument was divided into six categories consisting of the main phases of the inquiry process (see Tables 3 and 5). These categories include Orientation/Driving Question, Making Observations, Gathering Evidence, Considering New Evidence, Conclusion, and Communication. Within each category are sub-categories that further describe attributes of inquiry that should be demonstrated. Table 3 illustrates the alignment of the inquiry steps analyzed by the instrument with the three main sources cited, Center for Science, Mathematics, and Engineering Education (2000), Pedaste et al. (2015), and Windschitl (2008).

Table 3

Alignment of Analysis Instrument with Selected Sources

Analysis Instrument	Center for Science, Mathematics, and Engineering (2000)	Pedaste et al. (2015)	Windschitl (2008)
Orientation/Driving question	Exhibits Curiosity; defines question from current understanding	Orientation	Setting broad parameters for the investigation
Making observations	Propose preliminary explanations or hypotheses	Questioning	Organizing what we know and what we'd like to know
Gathering evidence	Plans and conducts simple investigation	Hypothesis Generation	Generating Table hypotheses
Considering new evidence	Gathers evidence from observation	Experimentation	Seeking evidence through multiple forms of observation
Drawing Conclusions	Explains based on evidence	Explanation	Constructing an argument based on evidence, but also considers other possible explanations
Drawing Conclusions	Tests explanation		
Communication	Considers other explanations	Data Interpretation	Develop a defensible explanation of the way the natural world works
Communication	Communicates explanations	Conclusion	

Each sub-category was ranked on a 5 point Likert Scale, with a 1 meaning “missing or extremely poor” and a 5 meaning “exceptional.” It was anticipated that the vast majority of the projects will fall into the 2-4 range on the scale. However, the rating of 1 and 5 were also included on this instrument in order to allow for extreme cases on either end of the spectrum. Each main category received a total, allowing for greater dissemination of categorical strengths and weaknesses, along with an overall total for the whole project. Table 4 describes the scale used for initially analyzing each project.

Table 4

Explanation of the Rankings for Analysis Instrument

Likert Score	Category	Description and Example for the score
1	Missing/ Poor	Element is completely missing or done incorrectly. Example: Conclusions are based solely on existing data; no evidence of observational data is shown
2	Low	Bare minimum of the described trait is exhibited. Example: Evidence of observations are shown, but do not support reported conclusions
3	Medium	A good general sense of the inquiry process is indicated. Example: Each step of the inquiry process is completed, but some coherence may be missing for how each piece fits in the larger picture.
4	High	Very good at understanding and commencing the inquiry process. Example: Evidence is presented that new information is consolidated into current understanding and therefore affects a new understanding.
5	Exceptional	Extremely well executed in bringing stages of inquiry together. Example: Coherently synthesizes multiple sources of information, including personal observation, and proposes a defensible conclusion.

Each project has been de-identified. There would be no way to link an analysis grade with a particular student. The analysis grades are given as a reference to classify the overall understanding of the inquiry process. Table 5 provides a look at the actual instrument to be used in this investigation.

Table 5

Project Analysis Instrument

	Exceptional	High	Medium	Low	Missing / Poor
Orientation/ Driving Question	5	4	3	2	1
IDEA: Demonstrates the ability to form authentic, researchable question					
Ideas or circumstances that prompted the research question are explained					
Question posed can be answered through the proposed data collection.					
Question posed will lead to new understanding for the student - subject is likely not addressed in general k-12 education					
Defines questions - demonstrates deep understanding of the question					
Total					
	Exceptional	High	Medium	Low	Missing / Poor
Makes Observation	5	4	3	2	1
Exhibits curiosity - looks at more than the bare minimum.					
Uses appropriate tools to gather evidence					
Observations lead to further, related, researchable questions					
Uses background/prior knowledge (Use background knowledge to make observations or mentions background knowledge in some other context)					
Generates hypothesis, possible conclusions, or explanation					
Total					

(table continues)

	Exceptional	High	Medium	Low	Missing / Poor
Gathers Evidence	5	4	3	2	1
Physically collects information through specimens, notes, photos.					
Photographic evidence is of high quality and beneficial to answering the posed question					
Collects data through other means - books, Internet, experts					
Uses previous research findings					
Total					
	Exceptional	High	Medium	Low	Missing / Poor
Considers New Evidence	5	4	3	2	1
After talking to expert, considers new approach to the inquiry					
Incorporates new evidence into understanding					
Total					
	Exceptional	High	Medium	Low	Missing / Poor
Conclusion	5	4	3	2	1
Interprets data - Did they combine physical/photo evidence with existing expert data to come to a new understanding.					
Synthesizes more than one line of evidence to come to new understanding					
Bases conclusions on <u>own</u> observations (Consulting books/Internet/experts is okay)					
Adds to explanation of phenomenon					
Demonstrates an ability to transfer application to use in an elementary inquiry-based classroom					
Total					

(table continues)

	Exceptional	High	Medium	Low	Missing/ Poor
Communication	5	4	3	2	1
Presentation is aesthetically pleasing enough to effectively communicate process and findings of the inquiry investigation.					
Presentation contains quality information, supported by enough detail to make claims.					
Organization is logical and effective					
Total					
Overall Total for Project					
Inquiry Grade					
Narrative Summary					
Highlights:					
Issues or problems:					
General sense of the project:					

While evaluating each project, a score was assigned to each of the 24 specific descriptors within the six main categories. After each score, the researcher wrote a short comment that specified the reason for the score, noting anything exceptional that may have garnered a higher score or anything that was missing or incorrect that warranted a lower Likert scale score. After initial scoring was completed, the researcher analyzed the comments for each descriptor. Common words and phrases were noted and sorted to examine both individual and collective themes. The constant comparative method (Johnson & Christensen, 2008; Boeije, 2002; Glaser & Strauss, 1967) of data interpretation and analysis were used to constantly revisit, and potentially revise, scores

on the analysis instrument. The data were analyzed to determine themes, categories, relationships, and other circumstances to answer the research questions. Using these data, the researcher created a detailed rubric for scoring projects in each of the instrument's categories and descriptors to allow others to analyze the inquiry projects consistently through use of the rubric. This rubric (Appendix B) was then used by an outside evaluator to establish inter-rater reliability for the use of the evaluation instrument. The outside evaluator analyzed and scored 30 of the 141 projects that had been randomly selected. Table 6 displays the score correlations for the original investigator's scores and the outside evaluator's scores. The score correlations are for the total of each of the six categories. A correlation coefficient of 0.75 was deemed to be acceptable to establish reliability.

Table 6

Correlation between Principal Investigator's Scoring and that of an Outside Evaluator

Inquiry Category	Correlation Coefficient
Orientation	0.87
Makes Observations	0.93
Gathers Evidence	0.88
Considers New Evidence	0.85
Conclusions	0.89
Communication	0.95
Total Score	0.86

Data Analysis

Qualitative Analysis

The descriptive content analysis study involved the researcher in analyzing inquiry projects to determine how well each student demonstrated understanding of the inquiry process. According to Patton (2002), the purpose of qualitative analysis is to “gather comprehensive, systematic, and in-depth information” about the case at hand (p. 447). Wolcott (1992) indicated that the collection of data in qualitative research can be subsumed by “everyday terms such as *watching*, *asking*, and *....reviewing*,” (p. 21). Qualitative data was gathered to get a rich description of the phenomenon being studied.

Qualitative methodology is appropriate where:

- (a) Detailed, in-depth information was needed about certain programs;
- (b) The focus on diversity among, idiosyncrasies of, and unique qualities exhibited by individuals; and
- (c) The intent was to understand the program theory- that was, the staff members’ (and the participants’) beliefs as to the nature of the problem they are addressing and how their actions will lead to desired outcomes (Patton, 2002, p. 163).

In this study comment written by the principal investigator regarding what was done well with each project, what was missing from each project, and overall impressions of the project and how it affected the understanding of the finding for the entire study. Analyzing these comments yielded common themes found among all of the 141 projects.

Using this method, themes emerged that provided further insight into how to better analyze the projects. Coding of different comments led to the absorption of smaller themes into larger, more inclusive themes. Denzin and Lincoln (2003) wrote that coding, then emerging subcategories, categories, and themes will help discover relationships and themes to create meaning. As each comment was coded and similar themes merged together, a clearer picture of the preservice and practicing teachers' demonstrated understanding of the inquiry process emerged.

Through this work, the researcher developed a system for organizing, coding, and categorizing the data. Inter-rater reliability of independent scorers of the science inquiry projects was established when another researcher independently reviewed the inquiry projects submitted by the students using the developed rubric. The researchers discussed the emerging themes and determined what categories and codes should be highlighted based on the themes.

Quantitative Analysis

The data analyses used descriptive statistics. Descriptive analysis was used to document study findings using frequencies, percentages, and mean scores, where appropriate. Statistical comparisons were conducted using t-tests, correlations, and Cohen's d effect size. All data coding and analysis was conducted using Microsoft Excel software.

Protection of Human Rights

The research study has been approved by the Institutional Review Board (IRB) at the University of Northern Iowa. Anonymity and confidentiality has been ensured. All data will be destroyed at the conclusion of the study. Privacy and confidentiality will be given to all participants to ensure their freedom from harm or embarrassment. If results of the research are published, no subjects could be recognized on an individual basis.

Some of the data, consisting of 70 undergraduate student projects from 2012-2015, have signed consent to use images and wording of the slides in an article on using this sort of inquiry project in a science methods course. The instructor of the course obtained consent to use images taken from the projects and to acknowledge students in the acknowledgement section of the journal article whose work was featured in the article.

Summary

The descriptive content analysis described the understanding of the inquiry process of preservice and practicing teachers. This chapter discussed the choice of methodology, case and sample selection, data collection, and analysis methods. The next chapters will present findings of the research questions. In addition, the researcher will provide a discussion of the data analysis and implications of the study.

CHAPTER 4

RESULTS AND IMPLICATIONS

This investigation analyzed preservice teacher inquiry projects and practicing teacher inquiry projects to better understand how well these groups of future and current educators use the inquiry process. These projects were analyzed to: (a) determine the successes and problems students encountered in their presented inquiry projects; (b) to compare the projects made by preservice teachers to those of practicing teachers to determine the strengths, weaknesses, and the participant's general understandings of the inquiry process between these two groups; and (c) to recommend improvement to this sort of project for greater student growth in science inquiry understanding. The following research questions were used to guide this investigation:

1. How well do preservice and practicing teachers follow accepted inquiry procedures?
 - a. What information was included in the projects that exhibited preservice and practicing understanding of the inquiry process?
 - b. What was missing from, or incorrect within, the projects that indicate lack of full understanding of the accepted inquiry process?
2. Is a practicing teacher's demonstrated understanding of the science inquiry process after obtaining experience in the classroom different from that of a preservice teacher?

Chapter 4 provides a general summary to describe the inquiry projects, specifically detailing the major project topic categories. Second, the chapter presents information on how well preservice and practicing teachers followed the inquiry procedures, focusing specifically on what these teachers did well regarding the inquiry process and what problems were observed. Third, the chapter provides a description of the differences in application of the inquiry process between practicing and preservice teachers.

Summary of Major Characteristics of the Inquiry Projects

One hundred forty-one projects were classified and analyzed. There was a wide variety of project themes ranging from broad topics like clouds, trees, or birds to very specific inquiry investigations focused on nature such as Kansas wildflowers, rhododendrons, tumbleweeds, and wetland ecosystems. To present the student chosen topics, theme categories were grouped together by similarities. For instance, trees identification, leaf identification, bark identification, shrubs, fruit trees, oak trees, and evergreen trees were all grouped together in a category called Trees/Leaves/Bark. These separate topics were related closely enough to be compressed together into one, slightly broader category. Table 7 contains the inquiry project categories for all participants (n=141). Forty-two projects addressed trees, leaves, and barks. The second most common project category was animals and animal behaviors (n=26). Trees, leaves, and animals are parts of the natural world that come to mind immediately when a project focused on outdoors inquiry is mentioned. These topics were likely chosen because of their familiarity and the sense that were accessible to study.

Table 7

Inquiry Project Categories for All Participants

Project Category	Number of Projects	Percent of Total
Trees/Leaves/Bark	42	29.8
Animals/Animal Behaviors	26	18.4
Plants/Flowers	22	15.6
Clouds	22	15.6
Birds/Birdseeds/Birdhouses	11	7.8
Earth/Physical Science	11	7.8
Sunsets	7	4.9
Ecosystems	2	1.4
Total	141	100.0

Table 8 includes a summary of categories from the preservice teachers (n=106).

Thirty-three projects addressed trees, leaves, and barks. The second most common project category was animals and animal behaviors (n=18).

Table 8

Inquiry Project Categories for Preservice Teachers

Project Category	Number of Projects	Percent of Total
Trees/Leaves/Bark	33	31.1
Animals/Animal Behaviors	18	17.0
Plants/Flowers	17	16.0
Clouds	16	15.1
Birds/Birdseeds/Birdhouses	9	8.5
Earth/Physical Science	6	5.7
Sunsets	5	4.7
Ecosystems	2	1.9
Total	106	100.0

Table 9 illustrates the categories from the practicing teachers (n=35). Nine projects addressed trees, leaves, and barks. The second most common project category was animals and animal behaviors (n=7).

Table 9

Inquiry Project Categories for Practicing Teachers

Project Category	Number of Projects	Percent of Total
Trees/Leaves/Bark	9	25.7
Animals/Animal Behaviors	7	20.0
Plants/Flowers	6	17.1
Clouds	5	14.3
Birds/Birdseeds/Birdhouses	4	11.4
Earth/Physical Science	2	5.7
Sunsets	2	5.7
Ecosystems	0	0
Total	35	100.0

As identified in Tables 7, 8, and 9, there were many project categories. Even within these categories, there was variety. For instance, 42 projects focused on trees, however the content within those 42 projects varied greatly. For example, one tree project focused mainly on identifying trees in a specific geographic area. The student used leaves, bark, flowers, fruit, or a combination of them to make identifications. Another project honed in solely on the leaves, while others focused on the bark. However, there were other projects that fit into this category that demonstrated the process of making conclusions about trees, such as how leaf size might be related to amount of tree growth. Yet another project showed evidence of the participant observing several different trees over an extended time, noting the rate of color change in the leaves. The conclusions then

showed which leaves changed color first and which leaves changed color last, with the participant speculating on causes and implications.

Understanding the Inquiry Process

The first question guiding this research addressed demonstrated understanding of how well teachers, both preservice and practicing, conduct inquiry. Table 10 provides the overall scores, as determined by application of the analysis instrument, for both preservice and practicing teachers, as well as the group as a whole.

Table 10

Overall Scores for Inquiry Projects

Student Type	Overall Score of Inquiry Project out of 120 (SD)	Percentage (SD)
Preservice Teachers	88.3 (14.9)	73.6 (12.5)
Practicing Teachers	93.9 (11.3)	78.3 (9.4)
Both Groups Together	89.7 (14.30)	74.7 (11.91)

Note: Standard deviation in parentheses

The overall scores for the inquiry projects averaged 74.7% for the whole group of 141 projects. The highest score within the whole group was 99.2% and the lowest score was 40.8%. This shows quite a range of students' ability to conduct an independent inquiry project. Seventy-nine of the projects scored above that mean score, while 63 of the projects earned a score below that average.

The data showed preservice teachers had an overall mean score of 73.6% of the possible points and practicing teachers achieved a greater mean of 78.3%. Within the

group of preservice teachers, the highest score earned was 98.3% and the lowest score earned was 40.8%. The practicing teachers' projects had a high score of 99.2% and a low of 59.2%. Figure 1 shows graphed lines, each connecting the scores of preservice or practicing teachers. The shapes of the lines are similar except that the line of preservice teacher scores is somewhat lower and has a faster decline for the lowest scores. These findings indicate that there was a wide range of understanding within both groups, though the practicing teachers presented a smaller overall range. A few markedly-low scores seemed to have decreased the mean score for preservice teachers.

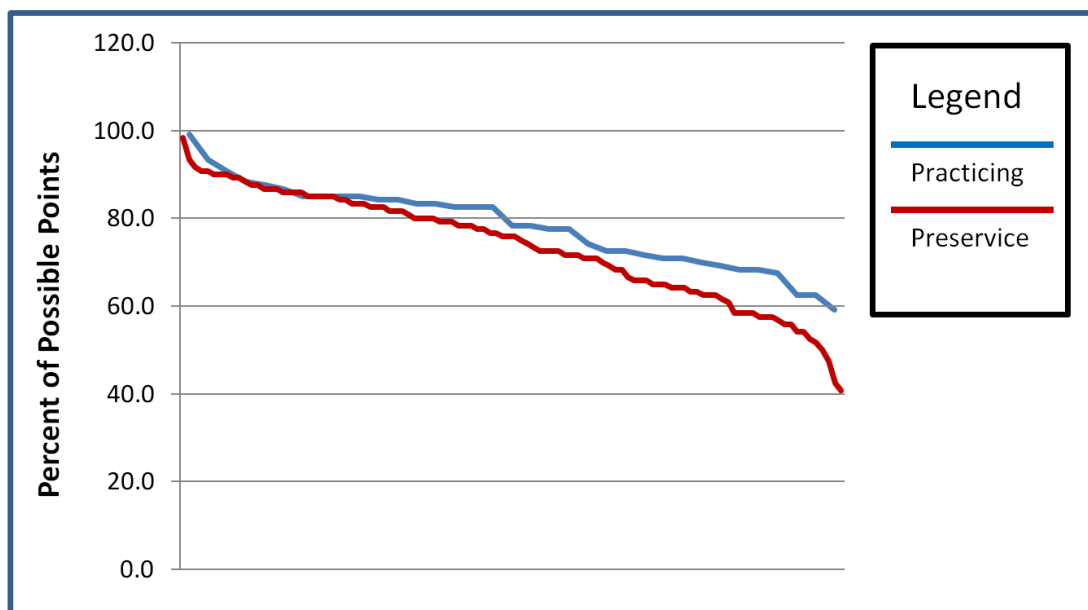


Figure 1. Distribution of Scores of Preservice and Practicing Teacher with Horizontal Axis Showing Scores of Individual Projects.

The analysis instrument included scoring criteria in six categories that collectively described the scientific inquiry process. The six categories were: Orientation/Driving

Question, Making Observations, Gathering Evidence, Considering New Evidence, Making Conclusions, and Communication. Table 11 shows the mean raw score and percentage of points assigned to projects for each category. The subjects in this study had the most difficulty with the Considers New Evidence category, earning only 43.0% of the possible points possible for this category. Project scores in the Gathering Evidence category received the highest percentage of points, at 83.0%.

Table 11

Overall Mean Scores for Each Category

Category Possible points	Possible Points	Mean Raw Score (SD)	Percentage of Possible Points
Orientation/Driving Question	25	19.2 (3.17)	76.8
Makes Observations	25	19.1 (3.56)	76.4
Gathers Evidence	20	16.6 (2.53)	83.0
Considers New Evidence	10	4.3 (1.96)	43.0
Conclusions	25	18.6 (3.79)	74.4
Communication	15	11.9 (1.90)	79.3

Note: Standard deviation in parentheses

The scoring point distribution of some projects was even across all categories, but other projects showed great variation in scores for different categories. Correlation coefficients were derived to determine if success (high scores) or struggle (low scores) in a particular category were connected to success or struggle in other assessed categories.

Initially, the score in each category was compared with the total score to discover what types of correlations may exist. Five of the six categories showed a strong

correlation to the overall project score. The only category that did not show a strong correlation coefficient was Considers New Evidence. This category had a Moderate correlation to the overall project effectiveness. This category was consistently the category in which students scored lowest because many participants either did not attempt to consult a knowledgeable professional, or consulted a person who was not an expert.

The authors of many projects were able to overcome this low performance in the Considers New Evidence category. Participants could have scored well on the overall project, even with a lower score in this category, if they had high scores in the other categories. Table 11 describes the correlation coefficients and interpretations for each category when compared to overall project score. Makes Observation had the highest correlation coefficient (0.943) and Considers New Evidence had the lowest correlation coefficient (0.416).

Table 12

Correlation between Total Scores and Specific Categories

Category	Correlation Coefficient	Interpretation
Makes Observation	0.943	Strong Positive
Conclusions	0.923	Strong Positive
Orientation	0.893	Strong Positive
Gathers Evidence	0.866	Strong Positive
Communication	0.847	Strong Positive
Considers New Evidence	0.416	Moderate Positive

Correlation coefficients were calculated between some of the separate categories that should have been connected through the design of the project. The creation of specific, researchable driving questions is a foundational component of inquiry (Center for Science, Mathematics, and Engineering Education, 2000; Windschitl, 2008; Pedaste et al., 2015). Those questions lead the entire investigation and can likely lead to projects that are either deep or shallow, depending upon the scope of the original questions. A strong correlation was found between the Orientation component, the part in which the questions are developed, and the ability to make good Observations (0.825 correlation coefficient) and the Conclusions phase (0.773 correlation coefficient). A moderate to strong correlation was found between the Orientation category and the Gathers Evidence category (0.697).

Observation is an important and primary process skill (Center for Science, Mathematics, and Engineering Education, 2000; Windschitl, 2008; Pedaste et al., 2015). To find out if it could be a determining factor in success or struggle in conducting inquiry, it was also tested for correlation with the Conclusions category. A strong correlation (0.850) was found between those two categories. Table 13 summarizes the findings related to correlations between these different inquiry categories. Makes Observation and Conclusions were the most strongly linked (0.850), while Orientation and Gathers Evidence had the lowest correlation, with a moderate to strong correlation with (0.697). The strength of observations made seems to directly relate to the strength of

the conclusions that can be drawn. Stronger and more detailed observations may allow for more defensible conclusions.

Table 13

Correlation between Other Categories in the Analysis Instrument

Categories	Correlation Coefficient	Interpretation
Makes Observations and Conclusions	0.850	Strong correlation
Orientation and Makes Observations	0.825	Strong correlation
Orientation and Conclusion	0.773	Strong correlation
Orientation and Gathers Evidence	0.697	Moderate/Strong Correlation

Specific Topics and the Inquiry Process

While evaluating the inquiry projects, the principal investigator kept a log of overall impressions regarding the entire dissertation project. Within that log, the principal investigator recorded noticing that certain topics seemed to score lower and were awarded lower scores as a scientific inquiry process. Two topics led to recurring comments about lack of quality displayed in the inquiry process. Those two topics were clouds and trees/leaves. The following is a sample of the comments made in the log describing overall impressions of the dissertation project for inquiry projects in the clouds and trees/leaves categories.

Clouds

“This project is missing a lot of needed components for inquiry. Student seems to be engaged in fact finding.”

“I am really wondering if identifying specimens can be done well as an inquiry project. So far, the ones I’ve seen have missed more points than the conclusion focused projects.”

“Nothing new or profound here. Very similar to other cloud projects I’ve seen. This was mostly a list of cloud types.”

“This was a low scoring project. This student seems to miss the entire point of inquiry. The author of this project really has created fact finding research project.”

“This student seems to understand the general idea, but hasn’t taken it deep enough.”

Trees/Leaves

“Nothing really exciting about this project. A very basic specimen ID (identification) project. Not a bad project, just not exciting inquiry.”

“This person does not appear to understand what scientific inquiry is. It would be difficult for the student to implement inquiry in a classroom without understanding it.”

“Again, the importance of questions. The student did kind of answer his first question. However, it was a fairly simple question, so led to simple identifications, looking at only one of many aspects of leaves. Is that a problem?? I’m not sure. I think for a college student/future teacher, this stopped short of its potential.”

“Been a steady decline since the eagles project. I hope this trend reverses. I’ve seen several undergrad projects that were much better than this.”

Because there seemed to be a trend emerging in which projects about clouds and trees or leaves demonstrated lower understanding than others, the projects totals for clouds and the project totals for trees/leaves were analyzed separately. For comparison, the project totals for 21 randomly selected projects that were not in the clouds or trees/leaves were used to compare against all the cloud projects. Thirty-seven randomly

selected projects that were not clouds or trees/leaves category were used to compare with all projects in the trees/leaves category. Tables 14, 15, and 16 illustrate the mean raw score for each analysis instrument category, the corresponding percent of possible points, as well as a mean project total score, with corresponding percentage. Table 14 shows mean scores for projects in the clouds category. Gathers Evidence had the highest percentage of possible points (74%) and Considers New Evidence had to lowest mean (39.0%).

Table 14

Scores for Projects in the Clouds Category

Category Possible points	Mean Raw Score (SD)	Percentage of Possible Points
Gathers Evidence 20	14.8 (2.1)	74.0
Communication 15	10.7 (1.8)	71.3
Orientation/Driving Question 25	16.4 (2.4)	65.6
Makes Observations 25	16.5 (3.4)	64.4
Conclusions 25	15.8 (3.5)	63.2
Considers New Evidence 10	3.9 (1.8)	39.0
Total 120	78.0 (12.5)	65.0

Note: Standard deviation in parentheses

Table 15 shows projects in the trees, leaves, and bark category and Gathers Evidence had the highest percentage of possible points (74%), with Considers New Evidence scoring the lowest (42.0%). These two categories were consistently the highest

and lowest of the six. As discussed earlier, Gathering Evidence was likely the highest scoring category simply because a project could not have been completed with some kind of evidence being presented. Therefore, most students scored relatively highly on this category. Many students also scored low on the category of Considers New Evidence simple because they neglected to complete this portion of the inquiry process. Table 15

Table 15

Scores for Projects in the Trees/Leaves/Bark Category

Category Possible points	Mean Raw Score	Percentage of Possible Points
Orientation/Driving Question 25	18.3 (3.4)	73.2
Makes Observations 25	18.3 (3.3)	73.2
Gathers Evidence 20	16.6 (2.3)	83.0
Considers New Evidence 10	4.2 (1.8)	42.0
Conclusions 25	18.0 (3.8)	72.0
Communication 15	11.7 (1.7)	78.0
Total 120	87.1 (13.7)	72.5

Note: Standard deviation in parentheses

Table 16 shows projects in the randomly selected other category and Gathers Evidence had the highest percentage of possible points (85%), and again, Considers New Evidence has the lowest mean score (46.0%).

Table 16

Scores for Projects in the Randomly Selected Other Categories

Category Possible points	Mean Raw Score	Percentage of Possible Points
Orientation/Driving Question 25	20.6 (2.7)	82.4
Makes Observations 25	20.6 (2.8)	82.4
Gathers Evidence 20	17.0 (2.2)	85.0
Considers New Evidence 10	4.6 (2.1)	46.0
Conclusions 25	20.1 (3.1)	80.4
Communication 15	12.5 (1.9)	83.3
Total 120	95.5 (12.2)	79.6

Note: Standard deviation in parentheses

Some conclusions can be drawn just by looking at means of each of the three categories presented in the preceding three tables. However, to find statistical evidence of significance differences among the three categories, one-tailed equal variance *t*-tests were run and Cohen's *d* effect size were determined (see Table 16).

The data presented in Table 17 indicates a significant difference between projects in the clouds category and those from categories other than clouds or trees/leaves.

Table 17

Comparison of Clouds Category and Randomly Selected Other Categories

Category Possible points	Mean Raw Score Clouds (SD) n=21	Mean Score Randomly Selected Other Categories (SD) n=21	Equal Variance <i>t</i> - Test Against Randomly Selected Others	Equal Variance <i>t</i> -Test All Other Projects	Cohen's <i>d</i> Effect Size
Orientation/Driving Question 25	16.4 (2.4)	20.6 (2.7)			
Makes Observations 25	16.5 (3.4)	20.6 (2.8)			
Gathers Evidence 20	14.8 (2.1)	17.0 (2.2)			
Considers New Evidence 10	3.9 (1.8)	4.6 (2.1)			
Conclusions 25	15.8 (3.5)	20.1 (3.1)			
Communication 15	10.7 (1.8)	12.5 (1.9)			
Total 120	78.0 (12.5)	95.5 (12.2)	<.001	<.001	1.417

Note: Standard deviation in parentheses

The mean score of the projects that were classified in the cloud category was 65% of the possible points. To ensure there was no bias against cloud projects, the principal investigator reviewed total scores for projects in the Clouds category, as well as the comments written at the time of evaluation for each of the cloud projects. Though the lowest score earned in this category was 42.5%, there were projects that earned much higher percentages than this. The four highest cloud projects scored 85.8%, 80.8%, 76.7%, and 74.2%. These are far from the highest scores when compared to all the

inquiry projects in this study, but it also indicates that a cloud project was not automatically scored lower just because of the topic.

The following comments were found in the overall dissertation notes for the scoring of inquiry projects, all written after evaluating a project about clouds.

“Good to see a specimen identification project that looked good and really was full of authentic inquiry. I feel like this is another example of a student front loading info and then going to look for observations to match. It does help them better understand their world, so can be seen as inquiry.”

“When I previewed this, I initially thought it was going to be another project in which the student just listed cloud types the student found online. However, I found it at least has personal photos of 10 cloud types, so must have taken some time to complete this investigation.”

“With more and more above average projects, I’m starting to wonder if my initial thoughts about most (specimen projects, clouds especially) not understanding inquiry might have been a little too broad brushing. There have definitely, been some good ones that represent good inquiry.”

Though there is strong evidence that students choosing to do their inquiry projects about clouds earned the lowest overall scores, each project was given full consideration and when effective inquiry was conducted, it was noted and acknowledged. The generally poor quality of projects within the clouds category, along with the next lowest scoring topic of trees and leaves, could be due to many factors. First, it appears that specimen identification projects as a whole generally scored lower than projects focused solely on drawing conclusions. This was captured several times in the overall dissertation comments recorded by the principal investigator.

“This student has definitely gone to fact finding for the conclusions. Missed the point of inquiry.”

“Not a great project. This student seems to miss the entire point of inquiry. This project involves a lot of fact finding.”

“This is a student that I feel really does not understand inquiry. She is motioning through some of the steps without really thinking, just recording ideas that seems to fit.”

“Still a bit skeptical about specimen ID working as well for inquiry. I think it can be done, but it seems to be so easy to slip into finding a list of examples you are looking for, then trying to find observations.”

Identification projects were likely easier to complete because there are so many guides available to aid identification. This may have appealed to some students who saw the project more as a task to be completed, rather than as a way to improve their understanding of the inquiry process. Clouds could have been seen as something that could be easily observed and identified, thereby requiring less effort to complete the project. The main problem is that an investigator who really wanted to identify clouds through the process of inquiry would need several days, and possibly several locations, to personally observe a number of different cloud types, along with the kinds of weather conditions that accompany those cloud types. Very few of the participants who created the projects in this study made the effort to do this. Therefore, they often resorted to the fact finding approach in completing the assignment. Very similar comments could be made for the projects related to tree and/or leaf identification, the next lowest scoring category of projects.

Table 18 compares scores for projects in the trees category with randomly selected projects there were significant differences in four of the six categories. The Cohen's *d* effect size also indicated medium to high effect size for those same four categories. Only Gathering Evidence and Considers New Evidence did not show significant differences. These two categories also had a low effect size, as determined by the Cohen's *d*. Lack of significant differences in the Gathers Evidence category could be attributed to the fact that all projects required that some kind of evidence be gathered in order for the project to be completed.

Table 18

Comparison of Trees/Leaves/Bark Category and Randomly Selected Other Categories

Category Possible points	Mean Raw Score Trees n=38	Mean Score Randomly Selected Other Categories n=38	Equal Variance <i>t</i> - Test Against Randomly Selected Others	Equal Variance t-Test All Other Projects	Cohen's <i>d</i> Effect Size
Orientation/Driving Question 25	18.3 (3.4)	20.6 (2.7)			
Makes Observations 25	18.3 (3.3)	20.6 (2.8)			
Gathers Evidence 20	16.6 (2.3)	17.0 (2.2)			
Considers New Evidence 10	4.2 (1.8)	4.6 (2.1)			
Conclusions 25	18.0 (3.8)	20.1 (3.1)			
Communication 15	11.7 (1.7)	12.5 (1.9)			
Total 120	87.1 (13.7)	95.5 (12.2)	.003	.005	.647

Note: Standard deviation in parentheses

Even the lowest scoring project had accompanying photographs and/or existing information that were shared. When examining the overall results for each category, Gather Evidence had the highest mean score, 83.0% (see Table 10) indicating that most students did well in this category. Since most did well here, statistically speaking, there is not a significant difference between groups, as indicated in Table 18.

Conversely, the evaluation instrument category of Considers New Evidence was the category with the lowest overall mean score, 43.0% (see Table 11). The authors of the vast majority of the projects struggled in this category, mostly because the student investigators simply did not take this step to strengthen the conclusions in the inquiry project. Because most struggled with this, across all topics evaluated, there was no significant difference found between trees projects and the projects with other randomly selected topics.

As indicated above when discussing the cloud project category, the projects in the trees/leaves category tended to score lower, as did many projects that worked to identify specimens. Though there were some high quality tree projects, 90.9%, 87.5%, 86.7%, 85%, there were also many in which the author did not expend the effort to engage in inquiry, instead, the author consulted tree guides to find local trees and to list some facts about them. This fact-finding practice of many students caused the overall category of trees/leaves to score lower on average than projects in other categories. The category of clouds and the category of trees/leaves tended to earn the lowest scores of the projects that were evaluated (see Table 19).

Table 19

Comparison of Trees/Leaves/Bark Category and Clouds Category

Category Possible points	Mean Raw Score Trees	Mean Raw Score Clouds	Equal Variance <i>t</i> -Test	Cohen's <i>d</i> Effect Size
Orientation/Driving Question 25	18.3 (3.4)	16.4 (2.4)		
Makes Observations 25	18.3 (3.3)	16.5 (3.4)		
Gathers Evidence 20	16.6 (2.3)	14.8 (2.1)		
Considers New Evidence 10	4.2 (1.8)	3.9 (1.8)		
Conclusions 25	18.0 (3.8)	15.8 (3.5)		
Communication 15	11.7 (1.7)	10.7 (1.8)		
Total 120	87.1 (13.7)	78.0 (12.5)	.003	.647

Note: Standard deviation in parentheses

As the data in previous tables and foregoing discussion demonstrate, there were significant differences when comparing those two project categories with a random sampling of other projects that were of different topics. Table 18 compares those two lower point total categories. Based strictly upon mean scores for each evaluation instrument category, projects about clouds earned the lowest scores. The difference in total points between the two types of projects was significant with a medium effect size (Cohen's $d = .647$) Based upon this evidence, it can generally be concluded that projects in the category of cloud identification tended to be the examples of inquiry that scored the lowest, indicating a lower student understanding of the authentic inquiry process.

Evidence of Good Inquiry Process Understanding

As outlined in sub question 1a, part of this study was designed to help determine what evidence existed to indicate which parts of the inquiry process were properly undertaken. As each descriptor within each category was evaluated, the investigator made notes about the reasons for each of the rubric scores. This information helped to form the scoring rubric used by the outside evaluator to establish inter-rater reliability for the evaluation instrument. Additionally, once each inquiry project was evaluated within the inquiry categories, notes were made regarding specific things that the investigator felt were done well within the project. Notes were also made regarding where the investigator felt there were omissions or incorrect procedures. Those results will be shared in the next section. This section will focus those practices that were done well, in light of the project requirements and accepted inquiry procedures.

There were 186 comments recorded while evaluating the inquiry projects that highlighted what the preservice and practicing teachers did well. Though there were only 141 projects evaluated, some projects had multiple different comments recorded. These comments were reviewed to locate common emerging themes. Though there were quite a wide variety of comments made about the highlights of the projects, they were condensed into eight themes (see Figure 2).

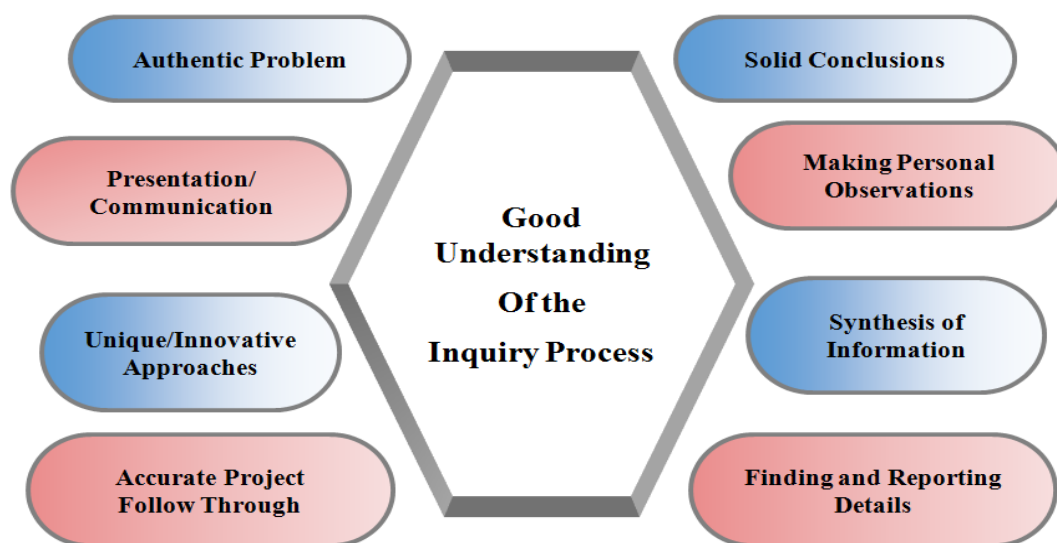


Figure 2. Main themes that emerged for good understanding of the inquiry process

Authentic Problem

Some projects that were evaluated stood out because the problems that the authors had chosen to solve or the questions they had chosen to answer seemed to come from a true, authentic place in the students' lives. The Center for Science, Mathematics, and Engineering (2000) discusses the need for exhibiting curiosity and defining questions from previous experience and background knowledge when engaging in scientific inquiry. Pedaste et al. (2015) describes the phase of inquiry that includes orientation and conceptualization. This phase includes the process of stimulating curiosity about a topic and addressing problem statements that aim to satisfy that curiosity.

Projects that stood out in this area went beyond looking at broad, generic topics such as clouds, trees, or leaves. A project that received a comment related to authentic problems may have addressed the student's personal environment. Examples may include

projects in which the author sought to figure out what was eating the tulips in one student's garden, figuring out deer movements for a student that desired to hunt them, or discovering what types of vegetables can be grown easily in a home garden for someone that's never gardened before. These were problems that these students wrestled with and in which they had an authentic desire to help makes sense of their world.

This is not to say that projects that focused on trees or clouds could not be classified as having authentic problems. A successful project focused on identifying the different trees, both shade and fruit, that existed on the student's family's new country homestead. It was a new area to explore and the family had a true desire to understand the wide variety of trees that surrounded their new home. Another student detailed his desire to better understand fossils because it was something teachers were required to teach in his school district. Because the student, a practicing teacher, had a real reason for wanting to make better sense of the world of fossils, this project also could be described as having an authentic problem.

Unique/Innovative Approaches

Though not specifically described as a necessity for authentic scientific inquiry, some projects were striking in the way their authors approached the problem they set out to solve. This included students that were exceptionally thorough in their investigation, bringing in more data sources than were required and putting all of that information to use in answering the research questions. For instance, one student brought in her 10 year old sister to conduct the inquiry along with her. She then made notes throughout the project presentation about how she used evidence to come to conclusions and how her

school age sister did the same. Other projects that classified as fitting this theme had authors who reported the use of instruments beyond that of camera and a field notebook. Some projects made use of trail cameras, anemometers, bird feeders, or extended field trips to unique environments. These unique approaches often led to interesting projects with a large amount of varied information with which to synthesize and generate solid conclusions.

Accurate Project Follow Through

This theme refers to the way a student followed the requirements of the project and completed needed tasks. It also refers to a student making claims in the project plan, and then fully executing those plans over the course of the investigation. This is a theme was not directly noted on the evaluation instrument and is not a process that is unique to the inquiry process. However, it still was noted in the comments when the highlights of each project were being noted because it still is a necessity for a project to be well done. Without accurate follow through, conclusions and synthesis may not be complete. Many projects that scored high on the evaluation instrument could have received this comment. However, a comment in this category was usually noted when there was something went above and beyond what was required in the assignment. For example, one student included an extra slide at the end of the presentation to show how each of the original questions had been addressed and answered. Another project author included photos of related activities they had piloted with school age children related to this topic.

Solid Conclusions

Windschitl (2008) wrote that the goal of scientific inquiry should be “developing defensible explanations of the way the world works” (p. 955). Defensible explanations are found in these projects in the conclusions and identifications that students presented. The conclusions were the culmination of all the work of the inquiry projects. The initial curiosity, the driving questions, the evidence gathering by research and personal observation all eventually lead to the moment at which the learner drew conclusions.

A solid conclusion was directly related to the driving questions asked earlier in the project and combined and synthesized multiple sources of information. Each piece of information was specifically highlighted and there was a clear path from observations and existing information to each particular conclusion. Conclusions were made stronger when organized to build upon each other. A solid conclusion was presented by itself, and then that conclusion was used as further evidence for another conclusion. In this way, all the conclusions had a sense of continuity and worked together to develop a defensible explanation of the way the part of the world the project addressed works.

Making Personal Observations

The gathering of evidence is an essential piece of the scientific inquiry process (Center for Science, Mathematics, and Engineering Education, 2000; Pedaste et al., 2015; Windschitl, 2008). Observation may take place before driving questions are written, with those initial observations sparking the curiosity of the person conducting scientific inquiry. Observations are also essential within the main process of inquiry when a person is trying to make sense of the world. Windschitl (2008) describes the process of seeking

evidence as driven by the desire to create a defensible explanation. The Center for Science, Mathematics, and Engineering Education (2000) elaborates on the importance of personal observation in the inquiry process:

Science distinguishes itself from other ways of knowing through use of empirical evidence as the basis for explanation about how the natural world works. Scientists concentrate on getting accurate data from observation of phenomena. They obtain evidence from observations and measurements taken in natural settings... (p. 25-26).

Projects that received comments related to this theme generally had a plethora of observational data throughout all phases of the inquiry project. The observations came in the form of personal photos, field notes, comments on original experiments, or even interviews with experts in the chosen field. Notes of observations prior to the inquiry project may also have played a large role in the project, helping to build the case as why the student wanted to conduct the scientific inquiry project in the first place. Adding these observations into the evidence for each of the conclusions or identifications was done effectively, emphasizing the importance of personal observation in the course of the project.

Synthesis of Information

The effective synthesis of multiple data sources was not a specific task that was required in the assignment details of this inquiry project. However, to make conclusions that were based on evidence, students were best served to effectively integrate data from many sources and provide evidence that those multiple sources supported each other. Pedaste et al. (2015) detailed the work of inquiry included the process of meaning making from the collected data, including the synthesis of new knowledge. This synthesis

led directly to new explanations. The Center for Science, Mathematics, and Engineering Education wrote the following:

Explanations are ways to learn about what is unfamiliar by relating what is observed to what is already known. So, explanations go beyond current knowledge and propose some new understanding. For science, this means building upon the existing knowledge base. For students, this means building new ideas upon their current understandings. In both cases, the result is proposed new knowledge. For example, students may use observational and other evidence to propose an explanation for (various natural phenomena) (p. 26-27).

The projects that were classified under this theme really distinguished themselves from the projects that did not. The information analysis and synthesis was very evident and detailed on the part of the student. It was very clear to the viewer that many sources of new information were combined with prior knowledge to create a whole new understanding. Students that did this well included an example such as describing how four different books were cross-referenced and then combined with personal observations to come to conclusions. Another student provided evidence for the use of existing information combined with personal observations related to different bird nests. However, this student consulted an expert, a local naturalist, and then revised and added to her conclusions. Based on comments and impressions throughout the evaluation process, the strong synthesis of multiple information sources was a great predictor of success in the scientific inquiry process. This theme also included projects that effectively involved suggestions from interview of experts into creating new understandings and conclusions.

Finding and Reporting Details

There were some authors of projects that were very good at reporting specific information details. Many projects noted as finding and reporting details were in the identification project category, though this description was not limited to identification projects only. The inclusion of a myriad of facts did not necessarily equate to a well-conducted inquiry project, especially when these facts were presented without continuity with the rest of the project or without synthesis with other sources of information. When an extraordinary amount of details was included, this was noted on the comments as a positive trait. Table 20 displays the number times comments occurred in each of the themes that were described above.

Table 20

Themes Regarding Positive Inquiry Understanding

Theme	Number of Occurrences out of 186
Making Personal Observations	40
Unique/Innovative Approaches	31
Synthesis of Information	29
Authentic Problem	25
Finding and Reporting Details	19
Accurate Project Follow Through	17
Presentation/Communication	16
Solid Conclusion	8

Problems or Omissions in the Inquiry Process

Sub question 1b involved investigating specific problems and omissions that prevented demonstration of the scientific inquiry process. As was mentioned in the previous section, comments were recorded by the investigator during scoring of the inquiry projects about omissions, problems, or other inaccuracies in the projects. Each project received at least one comment in the category, even if the comment was “No major problems.” Other projects received more than one comment regarding problems or omissions in the inquiry process. Overall, 183 comments were recorded related to inquiry process problems and omissions, as well as inaccuracies presented within the projects. Analysis of these 183 comments allowed six main themes to emerge. These themes included Fact Finding, Weak or Incorrect Conclusions, Lack of Observation, Lack of Synthesis, Poor Presentation or Communication, and Lack of Follow Through (see Figure 3). There were projects that had comments suggesting that there were no omissions or problems with the project, though this was not deemed to be a theme, but an observation.

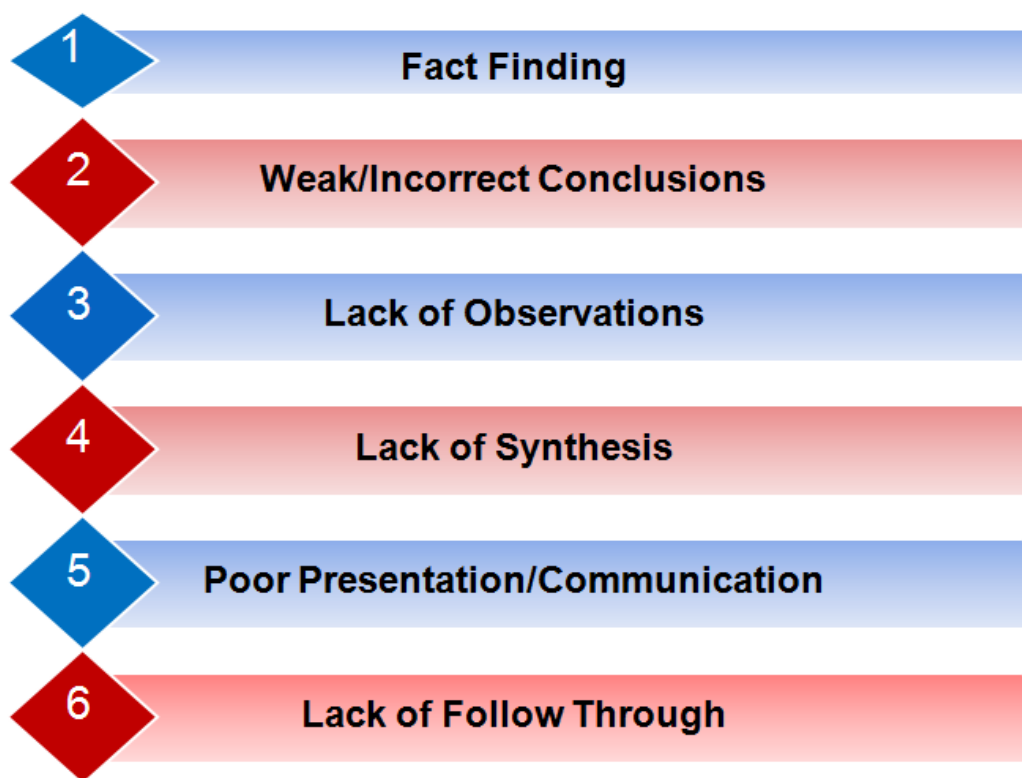


Figure 3. Main themes of problems and omissions identified in the inquiry projects

Fact Finding

The authors in the professional literature warn against several misunderstandings and misconceptions regarding authentic scientific inquiry. One of the most prevalent problems described is that of mislabeling a fact finding mission, such as a one-session Google search, as true scientific inquiry. Hutto (2012) warned against the distortion of the scientific inquiry process and students engaging in simple fact finding missions that were incorrectly labeled as inquiry. He believed that the process originally designed to help explain natural phenomena using inference has been diluted to little more than fact

finding exercises. Though Hutto (2012) understands that fact finding is an integral piece of scientific inquiry, he contends that much inquiry stops there and is passed off as real science, when, in fact, nothing new comes of the investigation, other than a synopsis of what others have already found.

Power (2012) found students who held the belief that all the information that one would need for a scientific investigation can be gathered in one single search activity. Due to previous, poorly conceived experiences students had come to the conclusion that inquiry is basically fact finding, including such actions as exploring websites, organizing information, or just printing out all the information that they find. Windschitl (2009) reported that research done with preservice science teachers indicated that most participants described inquiry as collecting and analyzing data, but not connecting this data to underlying explanation or theory.

Within the body of projects that were evaluated, there were some that appeared to be exercises in fact finding. There was little to no evidence that the student conducting the inquiry was really interacting with the data or trying to connect it to underlying explanation or theory, as Windschitl (2008) described. These projects often included conclusions that contained only a list of facts that could likely not have been observed by the students themselves and photos that were found online, not taken personally. For example, one student looked at oak leaves for her project. After presenting some basic conclusions such as listing the colors oak leaves may turn, the student went on to list facts about chlorophyll and different species of oak trees from various parts of the country. The conclusions about chlorophyll and different oak trees were accompanied by

photos found on the Internet. These conclusions often had little to do with each other and appeared to just hold the list of facts. In the end, these projects were seen to be mainly an exercise in fact finding.

Weak/Incorrect Conclusions

The main purpose of conducting scientific inquiry is to develop defensible explanations of the way the natural world works (Windschitl, 2008). These explanations mostly likely come in the form of conclusions about the meaning the data and observations. Pedaste et al. (2015) describes the Conclusion phase of the inquiry process as the phase in which the basic conclusions of the study are stated. In this phase, learners should be addressing their original research questions and determining whether they are answered or supported by the results of the study. The ultimate goal would be new theoretical insights.

The strongest conclusions came from a combination of personal observation and previous research information, along with other potential sources of data. These data sources could then be synthesized to come to a conclusion that had plenty of evidence. However, there were projects that did not do this effectively. These projects may not have included much evidence, making baseless conclusions. Some projects presented conclusions that did not match the evidence that had been gathered, or presented conclusions that were just simply incorrect. Some of these projects started off with good questions and a good plan, but the actual conclusions reached were weak and unsupported by strong evidence.

Lack of Observation

A large and important component in the inquiry process is the inclusion of personal observation. The Center for Science, Mathematics, and Engineering Education (2000) described observation as the first act for a person engaged in inquiry. In fact, observation may even take place before driving questions are written, with those initial observations sparking the curiosity of the person conducting scientific inquiry. Observations are also essential within the main process of inquiry when a person is trying to make sense of the world. Windschitl (2008) describes it as the process of seeking evidence to help create a defensible explanation. Within this is found multiple forms of observation, which include personal observations of the phenomena being studied. Pedaste et al. (2015) emphasized the importance of exploration and experimentation, both of which require the investigator to become personally involved in the phenomena and the data being collected.

Within the projects being evaluated, there were some that displayed very little personal observation of the topic being studied. Some projects did not include one single personally taken photograph or any report of personally experiencing the phenomena. With little evidence of personal observation, the projects typically felt forced and artificial. Sometimes there were observations noted, but only as an outside piece of knowledge or as a pretty picture to include in the presentation. The projects noted to have lack much personal observation typically also had struggles to come to defensible conclusions, often because they had very little real world evidence to better make the claims. These types of projects might also be listed within the theme of Fact Finding.

However, the two themes of Fact Finding and Lack of Observation emerged separately based on the comments that were written at the time of evaluation.

Lack of Synthesis

Lack of synthesis was another theme that emerged as the investigator's comments were analyzed. The synthesis that was lacking was typically between the different sources of information that contributed to answering the research questions. Pedaste et al. (2015) described this as data interpretation or making meaning out of the collected data and synthesizing new knowledge. Some projects fitting this theme presented information gathered from multiple sources, but did not make claims or draw conclusions. Either existing data was used to make the claim, or observations may have been used to make the claim, but the different sources were not brought together to complement each other. Claims and conclusions presented could have been much stronger, much more "defensible" (Windschitl, 2008), had the student investigator taken the time and effort to synthesize the multiple data sources.

This theme was the most commonly occurring theme that emerged from this research. This deficiency was noted 71 times out of 183 comments, and came out of a total of 141 projects evaluated. Lack of information synthesis is the most prevalent form of lack of understanding within the projects that were evaluated. This comment often accompanied projects that also had comments about weak or incorrect conclusions. Lack of synthesis seemed to be a consistent cause of those weak conclusions. Had more synthesis occurred, it is likely that the conclusions in those projects would have been stronger.

When a student prepared a project that was mostly a collection of facts, those facts did not serve the purpose of evidence to support solid and defensible conclusions. There was a lack of connection among the various sources of information and with the overarching themes of the topic they were studying. This is similar to what Windschitl (2009) found. He reported that research done with preservice science teachers indicated that most participants described inquiry as collecting and analyzing data, but not connecting this data to underlying explanation or theory. When there is no connection among facts and no connection with underlying theory or explanation, the investigation becomes a basic research project, but fails to be an example of authentic scientific inquiry.

Because synthesis was found to be such an important piece of the scientific inquiry process, it is worth discussing possible reasons for such prevalence of lack of synthesis. For one, the requirements of the assignment did not specifically call for the evidence information synthesis. Students were not directed specifically to synthesize multiple information sources, though it may have been implied. Preservice or practicing teachers that have had little or no experience with conducting inquiry may not have even considered the need to synthesize different information sources.

Another possibility is that time crunches and other stresses may have stood in the way of fully completing the project. Despite having over half of the semester to work on this investigation, the students with multiple responsibilities and commitments may have felt hard pressed to complete this investigation, opting to do the bare minimum as outlined by the assignment. In cases like this, if a student even thought about the need to

synthesize, they may have thought of the process as the last step in the inquiry sequence and decided that they did not have time to complete that part of inquiry.

Yet another possibility exists to explain the lack of synthesis that was observed in these projects. As was discussed earlier, some projects in specific categories, such as cloud identification, tended to be weaker. One reason was that the projects might have been seen as being easier to complete because a lot of the information was already known. When much of the information is already known, there may have been a lack of authenticity in the entire process. If much of the presented information was known, there would be no apparent need to combine information to reach a new understanding. In attempting to complete the project, the authors of these types of projects might have followed the directions to present the necessary requirements. However, since no real inquiry was taking place, the presented information may have seemed forced or inauthentic.

Poor Presentation/Communication

Communication of investigation results is seen as an integral part of the inquiry process (Pedaste et al., 2015; Windschitl, 2008; Center for Science, Mathematics, and Engineering Education, 2000). All of the students participating in the inquiry project were required to create a presentation to display their work, acting as the communication instrument.

Although no student completely neglected to create a medium of communication, within that slideshow presentation, errors were found. These errors included spelling, grammar, or usage of the words in the text describing the investigation. Occasionally

students would misuse “there” and “their” or one student wrote several times about behaviors that deer exhibit in “breeding” season. It may also have to do with formatting errors that made slides difficult to read or understand. There were even a few presentations that still had some of the template text on them that was provided by the course instructor. The students sometimes just left the template text in place or added their own text near it. In a couple of cases, it also meant that the intent and follow through of the investigation was very difficult to discern from the slides presented. In any of the cases, these types of errors stole the credibility of the creator of the slideshow presentation. This, in turn, negatively affected the effectiveness of the communication. Though this does not set a good example for high quality inquiry, it may have more to do with lack of attention to detail or a hurried completion on the part of the student creating the project.

Lack of Follow Through

This category is more related to the specific inquiry project assigned as a graduate or undergraduate student and not as much to the general inquiry process. Issues included in this theme may be that the student simply did not follow the assigned procedures or did not complete requirements outlined in the course requirements for the assignment. It may also refer to instances in which the student said he or she would do something in the project plan, but then did not actually follow through with that piece of the project. Commonly, a student would mention in the project plan that he or she intended to talk with an expert in the field that was related to their topic. However, when all conclusions were listed and evidence was provided, there was no mention of follow through with that

particular part of the plan. One student that looked into sunsets only presented three total conclusions in her project presentation. It was as if this student just stopped her work on making conclusions and went on to complete the final part of the presentation.

Whether this was due to an oversight on the part of the student investigator or simply choosing to do the barest minimum to have something that could be turned in, the reason for this weakness may have more to do with the work ethic of the student and less to do with actual misunderstandings of the inquiry process. Though it is possible that pieces were left out because a participant did not understand how to complete it, other evidence pointed simply to lack of effort. Though not as specifically identified in the inquiry procedure, lack of follow through on the assignment, which was constructed so that students would experience the inquiry process, affected the overall efficacy of the project.

For some projects, there really was very little that was done incorrectly or left out. Some of the highest scoring projects addressed virtually every part of the inquiry process, as determined by the analysis instrument. Therefore, when it came time to comment on weaknesses, there were not any to be addressed, or any omissions were so insignificant that they did not negatively affect the inquiry project in any discernible manner.

Table 21 illustrates the number of times that comments emerged into the seven themes outlined above. Overall, Lack of Synthesis was the theme that occurred the most with the projects that were evaluated. Weak/Incorrect Conclusions was another theme that emerged quite frequently. Lack of the synthesis was likely a cause of weak or incorrect conclusions because neglecting to combine multiple supportive information

sources weakens a proposed conclusion. Those two themes accounted for more than half of the problems or omissions that were observed within the 141 projects included in this dissertation investigation.

Table 21

Themes Observed Related to Problems and Omissions in the Inquiry Projects

Theme	Number of Occurrences out of 183
Lack of Synthesis	71
Weak/Incorrect Conclusions	33
Lack of Observation	16
Fact Finding	15
Poor Presentation/Communication	15
Lack of Follow Through	13

Note: There were 19 projects that did not have any major problems or omission listed.

Examples of Inquiry Projects from this Investigation

This section better describes the evaluated inquiry projects. Projects are highlighted here that scored high, ones that scored in an average range, and ones that earned lower scores. Overall, there was a wide range of quality found in the projects. The project with the highest overall score was earned 119 out of 120 possible points, or 99.2% of the possible points. Eleven of the 141 projects scored 90% or better. The lowest scoring projects earned 49 of the 120 possible points, or 48.8%. Nineteen of the projects scored below 60% of the possible points. Therefore, there were 111 projects that scored between 60% and 89%. The following figures present representatives of each of these

categories: four slides from projects within the highest earning group, four slides from within the middle range group, and four slides from within the lowest earning group of projects. The 12 slides shown in the following 12 figures represent a sampling of two slides each from six different projects.

All of the slides shown come from the Conclusions sections of the projects. The conclusions were the slides that were best able to show how all parts of the investigation were brought together and synthesized to answer the questions that initially inspired the investigation. One of the major skill areas that differentiated the best projects from poorer projects was the ability to synthesize multiple information sources; therefore these slides of Figures 3-15 highlight differences in synthesis of information. The student's ability to deeply connect and consider information from multiple aspects of the investigation is what took a project from being a fact finding mission or an exercise in pure speculation to an investigation that was based on authentic inquiry.


Figures 3 and 4 are from one of the highest-scored projects. The student conducting the project investigated wind speed and its effects. These two slides really show well how this particular student synthesized multiple pieces of information. First, she wrote a detailed account of what she had observed in her own environment. To aid in her own observations, she chose to use the additional tool of an anemometer. The anemometer helped her make more detailed observations because she obtained numerical data such as specific wind speed at the locations she was observing.

Observations:
When I walk between Bender and Dancer Halls, I notice a significant increase in wind speed. I measured the wind speed between the towers and discovered it was 9.3 mph (higher than anywhere else I measured). I also measured the field beside Bender Hall and found it was 4.7 mph even though it is at the same elevation.

I explained this phenomenon to my dad, and he told me that the Venturi Effect causes the same high winds between skyscrapers.

I looked up the phenomenon and conclude that the wind is channeled between the towers, causing the wind speeds to increase significantly.

3. The wind speeds between the Towers are fast due to the Venturi Effect.



These are photos taken near Bender Hall. The photo on the left is taken in between the towers and the photo on the right is taken beside Bender Hall. These photographs were taken at 900 feet above sea level.


Figure 4. High Scoring Project Conclusion Slide 1

Observations:
Using a topographical map of Cedar Falls, I found out that the Thunder Ridge area is one of the highest points in town. The elevation in this area is 980 feet above sea level. I used my pocket-sized weather meter to measure the wind speed at this location . The wind speed was 6.4 miles per hour. This reading was higher than almost all of the other locations I tested.

An online article about wind power potential confirmed my findings that wind speeds are faster at higher elevations.

Therefore, I conclude that wind speeds are faster at higher elevations in Cedar Falls.

1. Wind speeds are faster at higher elevations.



This is me measuring the wind speed at one of the highest points in Cedar Falls.

Figure 5. High Scoring Project Conclusion 2

This student gave a quick summary of some existing information that she had found to support the observations she had made. Such supporting information could come from printed sources, as shown in this example in Figure 4, or from an expert in the selected field. In this case, she talked with her father who was an earth science professor at a small private college. In either case, she gathered pertinent information that eventually allowed her to come to reasonable conclusions. Both slides show a synthesis of her own observations and the information from other sources that led to a conclusion about wind.

Figures 5 and 6 are samples of another high scoring project. Again, these conclusion slides demonstrate the investigator using multiple data sources to eventually come to a logical conclusion that is supported by personal observation and other information sources. In this case, the project focused on learning more about rhododendrons, a plant that this student found growing outside of the student's new home. The student conducting this investigation sought to better understand how to care for this plant and allow it to thrive.


Observation:
Some of the leaves on the rhododendrons are yellowed.

My husband said that the yellow leaves still show green veins. He thinks that this is a sign of a sulfur deficiency. By adding sulfur, it will help decrease the pH of the soil.

An online article also says that rhododendrons grow better in soil with a low pH.

I conclude that rhododendrons require nutrients in the soil to grow properly. By adding sulfur, the leaves will not show a deficiency.

2. Rhododendrons require soil with a low pH.



Here are leaves that are yellowed with green veins. This indicates a nutrient deficiency.

Figure 6. High Score Project Conclusions Slide 3


Observation:
I noticed that some of the flower buds on my rhododendrons are not opening.

An article online said that rhododendron buds may not open in the winter due to wind and frost.

My rhododendrons on the west side of my house are not well protected.

I conclude that I should plant other plants to help protect my rhododendrons or move them to a place where they will be better protected from the elements.

6. Rhododendron buds need to be protected during winter.



Here is a rhododendron bud damaged by winter weather.

Figure 7. High Scoring Project Conclusions Slide 4


Similarly to the work of the student whose project is shown in figures 3 and 4, the student who created the project in Figures 5 and 6 made detailed observations. Then, the student's literature research uncovered existing information that helped to clarify the meaning of the observations. Synthesis of these information sources led to solid and defensible conclusions that demonstrate and enhanced understanding of the topic.

Observations: Boxelder bugs are known to hibernate during the fall-spring months. They look for crevices in buildings, behind siding, in and around windows and doorways, and inside homes. They are inactive during these months unless they are in a protected and warm place.

According to a reading, when tree buds open in the spring, the females come out of hibernation to lay their eggs on leaves and barks of ash or maple trees.

I have concluded that the boxelder bugs are using my apartment as their overwintering place. They have found crevices and cracks within my window and this is how they are getting into my apartment. It will be interesting to see if they leave during the next few weeks to go lay their eggs and live elsewhere since winter is now over.

6. The boxelder bugs try to overwinter inside homes, windows, walls, etc.



This photo shows a large population of boxelder bugs looking for a place to overwinter in. They will find cracks and crevices along siding, walls, windows, and doorways.


Figure 8. Average Scoring Conclusions Slide 1

Observations:
Boxelder bugs seek multiple ways to get inside homes, in the walls, and behind siding to stay warm during the winter months.


According to one of my sources, boxelder bugs will seek access to warm buildings through any cracks or crevices in foundations, doors, and windows.

After examining my window, it is clear to me how they are getting inside my window and into my room. There are multiple holes and cracks that they can crawl through to get from the outside to the inside of my window. There is also a tear in my protective screen on the outside of the window.

7. The boxelder bugs have plenty of ways to get inside my apartment.



Left: This is a photo of the outside of my window which faces the south. There are plenty of cracks in my screen which will allow boxelder bugs inside.



Right: This is a photo of my sister's bedroom window which faces to the East and is protected by a large bush so boxelder bugs don't take shelter there.

Figure 9. Average Scoring Conclusion Slide 2

The project in Figures 7 and 8 focused on Boxelder bugs and, more specifically, why there were large numbers of these insects found in certain parts of the student's home. Figure 5 contains a lot of information about Boxelder bugs and their winter behaviors. The first two paragraphs contain information that was found in existing sources, a key component in the inquiry process. The third paragraph then contains the conclusion that this student made based on that existing information. The investigator makes assumptions, which are likely correct, about the reason and method in which the bugs are entering her home. However, the slide itself does not have much personal information about observation. There are no anecdotal notes about seeing the bugs entering through any of the cracks around windows, or even looking for and finding

cracks in siding or around windows. The picture provided was found online and is not of the home of the student investigator.

There are implied observations and, looking at the project as a whole, one can see that the investigator did indeed photograph and observe many Boxelder bugs within the home during the late winter months. Despite having a lot of information, this student neglected to make conclusions more specific to the situation identified in the inquiry questions and just makes the broad statement that “The Boxelder bugs try to overwinter inside homes, windows, walls, etc.” This assertion could have been made based on a simple Internet search about the bugs. However, this project still scored in the medium/average range because of the overall attempt to examine a familiar phenomenon and make sense of it.

Figure 8 is a slightly stronger slide because it does bring in some personal observations and photos that the previous figure was lacking. This slide does a much better job of combining the existing information with personal observations. The main piece lacking in this slide is a close up photo of one of the cracks that were mentioned in the narrative section. An even better documentation would have been a photo catching the Boxelder bugs in the act of entering through those cracks. Again, this was an average project that showed the student investigator has some understanding of the inquiry process, but still needs to refine the thinking a bit.

Observations:
I did not observe any birds eating from the feeders. However, I did capture a picture of a few birds that were investigating the feeders. One bird that I was able to observe was an American robin.

I conclude that American robins are eating from the feeders because I often viewed them near the feeders.

1. American robins are one of the birds eating from the wild bird feeder.



This is a picture of an American robin near the bird feeders.

Figure 10. Average Scoring Conclusion Slide 3

Observations:
The birds that I observed near the feeders were often flying down off of a nearby branch or back up to a nearby branch. The feeders seemed to be out of the way for the birds to visit.

I conclude that the feeders were too low to the ground, and not close enough to surrounding branches high above.

9. The bird feeders were too low to the ground.



This is a photo that shows how low the bird feeders are to the ground.
Photo 21

Figure 11. Average Scoring Conclusion Slide 4

The project represented by Figures 9 and 10 focused on bird feeders and determining which feeders and types of feed were preferred by wild birds. The whole investigation was fairly well-planned and involved some experimentation and observation by the student investigator. Overall, this project was one the higher scoring in the middle range. Figure 9 shows a conclusions slide that features personal observation notes along with a student-taken photo with an arrow inserted to point the viewer to the intended bird. Based on the observations of the student, a conclusion was reached. The main issue with this conclusion is that no outside resource is consulted to help verify the observations. In actuality, robins seldom consume birdseed from feeders, preferring live worms and insects. If expert information about robins had been consulted, the student may have reached a more accurate conclusion, that the robin was likely prowling the ground around the feeders in search of live food. The effort and observations make this project a good attempt at inquiry and this investigator has a well-developed sense of scientific experimentation. However, the lack of synthesis with multiple data sources led to a less than defensible conclusion.

Figure 10 is similar in that it also includes some good observational notes and a photo from the person conducting the investigation. Again, the investigator makes a conclusion based on what was seen over the course of a few days at the bird feeders. Based on what was seen, the conclusion seems to make sense. Yet, if outside sources had been consulted while drawing this conclusion, this conclusion may have changed. In fact many birds are ground feeders and have no problem feeding on or near the ground. Additionally, it can be seen from the photo that the feeders are hanging from stands

specifically made for hanging bird feeders. One could surmise that because the stands were meant for the specific purpose of bird feeders, they would be at an appropriate level for most birds to comfortably feed. This is another example of the investigator getting a lot of things right about how to conduct authentic inquiry. However, the student lacked synthesis of multiple sources of data. The observations and photos are well done and help the investigator see a lot. The addition of factual information from the literature to those observations was lacking.

3. The temperature at 7:00 p.m. is 64 degrees

Observation:
The temperature of day has a contribution to the colors that the sunset appears to have.





Figure 12. Low Scoring Conclusion Slide 1

1. Colorado sunset at 6:35 p.m.



Observations: The time of the day plays a factor in the color of the sunset

Figure 13. Low Scoring Conclusion Slide 2


Figures 12 and 13 originate from a low-scored project. This particular project aimed to investigate sunsets. The conclusions slides are sparse and give very little information. The slide in Figure 12 contains a nice photo that is accompanied with a heading that appears to be an observation, but there is no explanation as to the relevance of this fact. To the right is a heading that says “Observation,” but then the text that is written appears to be more of an attempt at drawing a conclusion. This conclusion does not have any observational or existing information to back it up. There is no indication from where this statement was derived.

The slide in Figure 13 displays much of the same. Again, there is a statement that does not have any kind of evidence to support it. There is no comparison to the colors at other times of day or even any found information that would back this statement. This project only contained five conclusions, instead of the required 10, and all of the conclusions followed this format. Coupled with weak questions and a very unclear plan for the investigation, this project was the lowest scoring project of the 141 evaluated.

5. ALTOCUMULUS

Observation: These clouds are little individually but cover the sky. They are fluffy and look like cotton balls in the sky.


When you see Altopcumulus clouds in the morning you can expect thunderstorms in the afternoon.



Altopcumulus Clouds
<http://campbellscloids.wikispaces.com/Altopcumulus>

Figure 14. Low Scoring Conclusion Slide 3

<http://commons.wikimedia.org/wiki/File:Stratocumulus-cylinders.jpg>



Stratocumulus Clouds

6. STRATOCUMULUS

Observations: Stratocumulus clouds look like a series of cylinders.

Stratocumulus clouds form in rows and are usually low with blue sky between them.

Figure 15. Low Scoring Conclusion Slide 4

Figures 14 and 15 represent slides from one of the many cloud identification projects that were completed and evaluated. This cloud project scored quite low, mostly because it involved much “fact mining” misunderstood as scientific inquiry. Power (2012) described one misconception of what authentic scientific inquiry as the belief that all the information that one would need for a scientific investigation can be gathered in one single search activity. Power (2012) found that much of what was described as inquiry is, in fact, basically fact finding, including such actions as exploring websites, organizing information, or just printing out all the information that they find.

The project assembled a picture found online and some information about each particular cloud. The box labeled “Conclusions” is actually just a few facts about the clouds. It is possible that the student could have observed these characteristics in the clouds, but there is nothing in the slide to indicate that personal observation even occurred. In fact, the only personal photos were found in the introduction slides that outlined questions and important vocabulary. When it came time to really try to make sense of things in the conclusions, this student simply restated facts they had found in an Internet search activity.

Comparison of Understanding between Preservice and Practicing Teachers

The second main question that guided this research endeavored to determine whether a practicing teachers' understanding of the inquiry process after obtaining experience in the classroom differed from that of a preservice teacher. To determine this, the 141 projects were sorted according to status as a graduate or undergraduate student, resulting in 106 undergraduate and 35 graduate inquiry projects. The following table (Table 22) presents the initial data analysis for each of the evaluation instrument categories, as well as the overall mean for the two groups. Equal variance *t*-tests were performed and Cohen's *d* effect sizes were determined and interpreted.

Table 22

Project Comparison of Preservice and Practicing Teachers

Mean Totals	Preservice n=106	Practicing n=35	Equal Variance t- test	Cohen's d Effect Size	Interpretation
Orientation	18.9 (3.3)	20.0 (2.7)	0.034	0.44	Medium
Makes Observations	18.7(3.7)	20.4(2.8)	0.007	0.52	Medium
Gathers Evidence	16.4(2.7)	17.0(2.1)	Not Significant	–	–
Considers New Evidence	4.3(1.8)	4.5(2.3)	Not Significant	–	–
Conclusion	18.3(3.9)	19.5(3.3)	0.058	0.33	Small
Communication	11.7(2.0)	12.6(1.4)	0.007	0.52	Medium
Overall Out of 120	88.3(15)	93.9(11.3)	0.021	0.42	Medium
Percent of Possible Score	73.6(13)	78.3(9.4)	0.021	0.42	Medium

Note: Standard deviation shown in parentheses

These results indicate that graduate students (practicing teachers) scored better in every category of the analysis instrument. This difference was significant in three out of the six categories, as well as the overall mean score for the projects, when compared using a one-tailed, equal variance *t*-test. Additionally, one category, Conclusions, was very close to showing a significant difference, with a *t*-test value of 0.058. Those same categories all showed small to medium effect sizes, according to Cohen's *d*.

Two categories, Gathers Evidence and Considers New Evidence, were not significantly different. One major reason that the difference was not significant for the Considers New Evidence category is that most projects, both preservice and practicing teachers, had poor results in this category. The mean score for this category for all projects was 43% of the possible points. Practicing teachers had a mean of 45% and preservice teachers had a mean of 43%. Analysis of the notes taken while projects were being assessed also shows that this category was overwhelmingly the weakest part of most students' projects. Because both sets of students scored so poorly on this section, there was not a significant difference expressed within the data.

Conversely, most students, between the two groups, scored fairly well in the Gathers Evidence category. Preservice teachers earned a mean of 82% of the possible points in this category, while practicing teachers earned 85% of the possible points, on average. Though the practicing teachers did earn a higher mean, it was not significantly higher than the preservice teachers. The evidence gathering process was essential for this project and the vast majority of the participants did an effective job of pulling some kind of evidence together to help complete the project.

There are many possible reasons that the practicing teachers tended to score better according to the analysis instrument, indicating that they had a better grasp of what authentic inquiry entails. First, it seems that it generally matters if one has been in a classroom and possesses teaching experience to better conduct inquiry. It may be that the chance to have facilitated more science lessons in the classroom allowed a better vision of what inquiry science can or should look like. Teachers that completed this project and had several years of experience may have looked at the world with a child's perspective after spending so many years with children and leading their learning. Additionally, it could just be that the practicing teachers were generally older and more mature, taking this project more seriously and better exemplifying their understanding of the inquiry process.

A few other circumstances could have led to this significant difference between the apparent understanding of the inquiry process between the preservice and practicing teachers. The preservice teachers are undergraduate students who typically are taking 5 to 6 classes at the same time, potentially limiting the time available to really conduct a thorough inquiry investigation, whether they understood the inquiry process or not. The practicing teachers were likely taking only one class at the time. This would allow for more time devoted to this particular project, along with their in-classroom background knowledge.

Lastly, one might consider that these groups of preservice teachers were schooled entirely within the era of No Child Left Behind. Under No Child Left Behind, the pressure to move all students to prescribed levels of proficiency forced many school

districts and teachers to narrow their curriculum and streamline their pedagogical delivery methods (Jennings & Rentner, 2006). A heavy emphasis on mathematics and reading often cut into the time allocated to science (Griffith & Scharman, 2008).

Consequently, research indicates that students were exposed to fewer scientific concepts in smaller allotments of time (Marx & Harris, 2006). This rarely allowed for student-centered, hands-on science experiences. Students growing up in the age of No Child Left Behind have missed out on early, formative experiences in science (Marx & Harris, 2006). Missing these formative experiences may have truly made it more difficult for the preservice teachers to conduct authentic inquiry simply because they may never have experienced it themselves.

Without the background knowledge of his or her own personal experiences, one could speculate that the preservice teachers were at a disadvantage in displaying their inquiry abilities, because they may not have had any. Without extensive knowledge of each participant's educational experiences, this possibility is speculative. However, the results do match with previous findings regarding the effects of No Child Left Behind and indicate that preservice teachers have a less complete understanding the scientific inquiry process than practicing teachers.

Differences in Comments about Practicing and Preservice Teachers

In addition to the statistical evidence that practicing teachers tend to conduct inquiry better than preservice teachers, the comments that were written regarding highlights of the projects and the problems or omissions from the projects were also analyzed. The comments were sorted by practicing and preservice teacher and the first

comment for each project was considered. The first comment was generally the biggest issue that was observed about that project, both as a highlight and as a problem. The comments were grouped into themes discussed earlier.

The themes that emerged for the highlights of projects, or the things that were done well, included Authentic Problem, Presentation/Communication, Unique Innovative Approaches, Accurate Project Follow Through, Solid Conclusions, Making Personal Observations, Synthesis of Information, and Finding and Reporting Details. Table 23 compares the percentage of time that each of these themes emerged as the first comment for practicing and preservice teachers. Since the number of projects within each group is so different, percentage of the particular group is reported.

Table 23

Positive Themes for Practicing and Preservice Teachers

Theme	Percent of Preservice Teachers	Percent of Practicing Teachers
Authentic Problem	14.0	22.9
Presentation/Communication	9.3	5.7
Unique/Innovative Approaches	16.8	20
Accurate Project Follow Through	5.6	11.4
Solid Conclusions	3.7	2.9
Making Personal Observations	23.3	14.3
Synthesis of Information	11.2	14.3
Finding and Reporting Details	12.1	8.6

These data indicate that practicing teachers tended to ask more authentic questions, using unique or innovative approaches, accurately following through with the assigned project, and synthesizing information. Preservice teachers had a higher percent of positive themes when it came to the effective communication of the presentation, making solid conclusions, making personal observations, and finding and reporting specific details. It should be noted again that this percentage only represents the first comment given, typically the one that left the greatest impression.

Additionally, something positive was found for every project evaluated and those comments, in turn, were categorized into the eight major themes that emerged from the entire investigation. Therefore, even though the preservice teachers had a higher percentage of projects receiving a positive comment related to making personal observations, that may have been the only thing they did really well, and they consequently may have scored low on the overall project. However, these data still give some insight into what the two groups of participants generally did well.

In the same manner, all projects were sorted into preservice and practicing teacher categories and the comments related to the problems and omissions detected for each group were analyzed. As was discussed earlier, the major themes that emerged regarding problems or omissions of the evaluated projects were Fact Finding, Weak/Incorrect Conclusions, Lack of Observation, Lack of Synthesis, Poor Presentation/Communication, and Lack of Follow Through. Table 24 shows the percent of projects in each category that had comments in those seven themes as the first comment given.

Table 24

Problem and Omission Themes for Practicing and Preservice Teachers

Theme	Preservice Teachers (%)	Practicing Teachers (%)
Fact Finding	14.0	0.0
Weak/Incorrect Conclusion	29.9	2.8
Lack of Observation	11.2	11.4
Lack of Synthesis	48.6	54.2
Poor Presentation/Communication	10.3	11.4
Lack of Follow Through	7.5	14.3

Note: 15.9% of the preservice teachers and 5.7% of the practicing teachers were noted to have no major issues or omissions.

These data indicate that both groups had the biggest struggle with synthesis of information as they came to final conclusions and identifications. Although, it should be noted that when looking at the specific comments that fell in this theme, many of the practicing teachers were grouped into this category because of the lack of synthesizing expert data with the rest of the accumulated information. This also happened to a point with the preservice teachers. Nevertheless, this table suggests that the biggest struggle for both categories is effective synthesis.

These data also suggest that preservice teachers are generally more likely to mistake fact finding missions for inquiry and to present weak or incorrect conclusions. Lack of observation and poor presentation components that affected communication occurred at very similar percentages between both groups. The preservice teachers actually had a higher percentage of occurrences than the practicing teachers. Since each

project was given a comment related to problems or omissions found within, these data do not really indicate that one group of teachers had more or less problems. However, it does help to see the types of problems that each group of teachers tended to display.

Summary

Results of this research indicate that the projects analyzed for this study demonstrated a wide range in understanding of the process of scientific inquiry. Students preparing the projects ranged from an almost perfect demonstration of inquiry, 99.2% of the possible points on the evaluation instrument, to a very primary understanding of the process, represented by a project that earned only 40.8% of the possible points on the instrument. Analysis of the projects by each of the six categories on the analysis instrument showed the inquiry process of gathering evidence had the highest amount of success, while considering new evidence, especially in the form of experts in the field, was consistently lacking in many projects and earned the lowest mean score of all the categories.

It was discovered, through the course of this research, that there was a strong correlation between five of the six categories on the analysis instrument and the final score from the instrument. This meant that those that did well in those five categories typically did well on the project as a whole and those that did less well on any of those five categories tended to do less well on the overall project. The only inquiry process category that did not show a high correlation coefficient was Consider New Evidence, which tended to be the lowest category for a large number the projects evaluated.

Analysis of comments made after each project evaluation was completed led to the emergence of eight themes related to aspects of the inquiry process that preservice and practicing teachers did well. Making personal observations while in the process of an inquiry investigation was the most commonly occurring theme among all the projects. In addition, analysis showed seven themes that were recognized regarding problems or omissions in the understanding and demonstration of the scientific inquiry process. Lack of synthesis of informational sources was the most commonly occurring theme for all project evaluated.

The topics included in this analysis of inquiry projects varied almost as much as the total scores that were earned. These many topics included projects that both aimed to come to new conclusions and those that aimed to make identifications as their conclusions. Overall, identification projects scored lower and were found to be more prone to becoming a fact finding exercise. Among the project topics, clouds and trees and leaves showed the overall lowest scores, indicating the lowest demonstrated understanding of the scientific inquiry process. Of the two, projects focused on clouds showed the lowest understanding of inquiry.

On average, practicing teachers achieved higher overall scores on the projects than the preservice teachers, suggesting a generally better understanding of the process of scientific inquiry. Practicing teachers earned higher scores in all six categories on the analysis instrument and demonstrated differences that were statistically significant in four out of the six categories. Each group of students had a variety of highlights and problems or omissions shown in the inquiry projects. However, both groups showed the most

struggle with synthesizing multiple information sources to make fully defensible conclusion statement.

Chapter 5 will discuss the possible meaning and implications of these results, as well as suggestions for future research related to this topic.

CHAPTER 5

DISCUSSION AND CONCLUSION

This chapter provides a discussion of how the findings from the current investigation contribute to the literature related to preservice and practicing teachers' scientific inquiry. Suggestions to make future inquiry projects more successful are addressed. The current investigation analyzed preservice teacher inquiry projects and practicing teacher inquiry projects to better understand how well these groups of educators can implement the inquiry process. Projects were analyzed to: (a) determine the successes and problems students encountered in their presented inquiry projects; (b) to compare the projects made by preservice teachers to those of practicing teachers to determine the strengths, weaknesses, and the participant's general understandings of the inquiry process between these two groups; and (c) to recommend improvement to this sort of project for greater student growth in science inquiry understanding. The following were research questions guiding the study:

1. How well do preservice and practicing teachers follow accepted inquiry procedures?
 - a. What was included in the projects of preservice and practicing teachers that exhibited understanding of the inquiry process?
 - b. What was missing from the projects that indicate lack of full understanding of the accepted inquiry process?
2. Is a practicing teacher's demonstrated understanding of the science inquiry process after obtaining experience in the classroom different from that of a preservice teacher?

Summary of Findings

The first question that guided the current research was focused on how well the participants in the study, both preservice and practicing teachers, displayed an understanding of the scientific inquiry process. As a whole group, the 141 evaluated projects had a mean score of 74.7% (see Table 9), based on the points earned on the inquiry project evaluation instrument. If translated into traditional grades, this score would indicate a solid C average. This average indicates that there is some work that could be done to further help these groups of future and practicing teachers to understand the many intricacies of the scientific inquiry process. The scores within these 141 projects ranged from the highest percentage, 99.2%, to the lowest, 40.8%, indicating that within this sample the demonstrated understanding of science inquiry varied greatly. If all students are to receive the benefit of student-centered, inquiry based learning, all teachers need to have an appropriate understanding of the process itself, as well as an understanding of its benefits to long term learning.

Some research indicates that the presence of certain educational mandates has limited the amount of exposure to scientific inquiry that students have had over the past 15 years (Jennings & Rentner, 2006; Marx & Harris, 2006; Griffith & Sharman, 2008; Whitworth et al., 2013). This means that the teachers entering the field today may have experienced very little hands-on inquiry as students themselves, limiting their understanding of the inquiry process. Therefore, it becomes even more important for teacher preparation programs to increase the time and effort spent in instruction about, and practice in, the scientific inquiry process. A detailed understanding of what current

and future teachers already do fairly well and the problems they evidence, as determined in the current investigation, will inform instruction and practice and is described next.

What Was Missing from the Projects that Indicate Lack of Full Understanding of the Accepted Inquiry Process?

The sub questions of the first research question were concerned with recognizing what the preservice and practicing teachers did well and what they did not do so well. Based upon the mean scores on the evaluation instrument developed in the current investigation, the process of considering new evidence from expert sources was the area of inquiry with which students struggled most. This step required students to locate and consult with experts in a field related to their topic. This step was often done poorly or neglected entirely.

The current investigation determined themes that resulted from lack of demonstrated understanding of the authors of these inquiry projects. These themes (detailed in Figure 2) included Fact Finding, Weak or Incorrect Conclusions, Lack of Observation, Lack of Synthesis, Poor Presentation or Communication, Lack of Follow Through, and None. The most commonly occurring of these themes was Lack of Synthesis.

What Do Preservice and Practicing Teachers Do Well with the Inquiry Process?

The mean scores from the analysis instrument indicated that students performed best in Gathering Evidence. The mean score for all students in this inquiry phase was 83.0% of the possible points. Evaluation comments from the principal investigator were analyzed and arranged into eight main themes describing the evidence observed that indicated a good understanding of the inquiry process. These eight themes were Authentic Problem, Presentation/Communication, Unique/Innovative Approaches, Accurate Project Follow Through, Solid Conclusions, Making Personal Observations, Synthesis of Information, and Finding and Reporting Details. Of those themes, Making Personal Observations and Unique/Innovative Approaches appeared most frequently. The themes of Synthesis of Information and Authentic Problem also appeared quite often. The projects that evidenced skill in synthesizing information and the different phases of inquiry eventually became the exemplars for high quality scientific inquiry. Synthesis of information is an important feature in conducting authentic inquiry and the students that demonstrated this typically did quite well with the overall inquiry project.

Differences between Preservice and Practicing Teachers

The current study also examined differences in the demonstrated understanding of inquiry between preservice and practicing teachers. Results of the comparison between these two groups indicated that practicing teachers consistently scored higher in all phases of inquiry. This difference was statistically significant in four of the six phases of inquiry, Orientation, Makes Observations, Conclusion, and Communication. The overall mean scores were also significantly different.

Analysis of themes indicating a good understanding of inquiry showed that all eight of the positive themes were present for each group of teachers. However, these themes occurred at different frequencies. The most commonly occurring action that practicing teachers performed to indicate good inquiry understanding was to initiate an investigation based on an authentic problem. The most frequently occurring theme for preservice teachers was the ability to make personal observations.

The result of analysis of themes related to problems and omissions in the inquiry process showed that both practicing and preservice teachers had the same theme occur most often, the theme of Lack of Synthesis. In both cases, comments relating to a lack of information and process synthesis accounted for nearly half of all comments recorded. The theme of Fact Finding, or projects that presented information that was mostly pulled from existing research with little thought or synthesis, occurred within the group of preservice teachers, but did not occur within the group of practicing teachers. In general, it can be concluded that practicing teachers tend to demonstrate a better understanding of the scientific inquiry process than do preservice teachers, though the differences are not always significant.

Discussion: A Revised Model of What Makes a Good Inquiry Project

Chapter 4 described the themes that emerged when students demonstrated a good understanding of the inquiry process. These themes were displayed in Figure 2 as eight indicators of high understanding of the inquiry process. This section will take that model and revise it so that it reflects all the findings from the current investigation. A brief discussion of the points that indicated highly competent understanding of the scientific

inquiry process will precede the explanation for the revised model of good inquiry understanding.

From a strictly statistical perspective, the part of the inquiry process on which the participants in this study performed the best on was the phase of gathering evidence. The mean score for all participants in this category was 83% of the possible points (see Table 10). This large proportion of points indicated that the participants could find information that related to their topic. Evidence that the participants in this study were generally proficient at gathering evidence was also echoed in the principal investigator's scoring comments for each project, which were later organized into eight themes of good understanding of the inquiry process. Several professional literature sources indicate that the gathering of evidence is an essential piece of the scientific inquiry process (Center for Science, Mathematics, and Engineering Education, 2000; Pedaste et al., 2015; Windschitl, 2008). This information could be in the form of previously existing information that participants discovered with literature or Internet research, or it could be in the form of personal observations made about the environment being studied. In some cases, the information also came from participant-directed experimentation or from interviews with experts on the topics the participants were studying. No matter the sources, in general, the participants in this study knew how and where to find information that was related to their topic. This is not surprising as the gathering of information is not unlike any other research project that participants may have completed in the past. Through the use of textbooks, libraries, or Internet search engines, students are generally taught at a young age how to find information.

Two of the eight themes presented in Figure 3 are connected to the gathering of evidence: the themes of Finding and Reporting Details and Making Personal Observations. These two themes appeared 59 out of 186 chances when comments were made by the principal investigator about positive inquiry understanding (see Table 19).

This finding indicates that the preservice and practicing teachers in the study did other things well beyond the gathering of evidence. Participants also successfully chose an authentic problem, using unique or innovative approaches to conduct the inquiry-based investigation, accurately and fully following through with the project as assigned, and creating a presentation that that was logically constructed and effective at communicating the findings of the inquiry (see Figure 1). All of these themes are positive findings and generally indicate that all the teachers who created these projects have many of the skills necessary to fully implement authentic scientific inquiry.

The preceding four themes of choosing an authentic problem to research, using unique or innovative approaches to conduct the inquiry-based investigation, accurately and fully following through with the project as assigned, and creating a presentation that that was logically constructed and effective at communicating the findings are all good indicators that the teachers involved were coherently and correctly engaging in parts of the inquiry process. However, when taken separately, none of the four themes necessarily indicates that a participant understood and engaged fully in authentic scientific inquiry. Any of these four latest themes are also important to successfully completing a traditional research project at any number of points in a student's educational career. The ability to conduct research is a necessary skill for survival in school. Therefore, many of the

participants could effectively complete any of these facets of inquiry separately just by having the skills needed to progress through their school years. All of the themes discovered, being present and working together, is what was needed to achieve success in the act of authentic scientific inquiry.

There were some projects evaluated in this investigation that displayed excellence in most of the process of scientific inquiry. There were projects made by participants, both as preservice and practicing teachers that started off with an authentic problem and specific driving questions that steered the entire project. Those questions were then specifically addressed within the conclusions that were presented later in the project. These students did an excellent job of gathering the appropriate information and evidence to help answer their questions. This information was gathered from multiple sources, such as existing sources, personal observation and photos, and consultation with experts in the field. Then, this evidence was then seamlessly synthesized together so that each piece of evidence complemented another piece of information.

The synthesized information then led to solid, defensible conclusions that showed a new, deeper understanding of the chosen topic. In the best of these cases, conclusions were also somewhat synthesized, building upon each and making each other stronger. All of this was then communicated effectively. Presentations were polished, interesting, and included small details that made viewing them more efficient. This allowed all the new information and ideas presented to be effectively communicated, the final stage of the inquiry on which each participant embarked. While researching preservice teachers who were conducting inquiry, Windschitl (2009) reported most participants described inquiry

as collecting and analyzing data, but not connecting this data to underlying explanation or theory. This lack of connection is a lack of synthesis. Therefore, when synthesis occurs, the inquiry is likely to be richer and conclusions more defensible.

It was enjoyable and rewarding to view these types of projects. There is a sense of relief that there are teachers out there, both current and future, that demonstrate a good understanding of the scientific inquiry process. One can speculate that this good understanding would translate to appropriate use in classrooms, to the benefit of young learners. This is the ideal that should be the goal for all teachers, preservice and practicing. This research suggests that, though there is some higher understanding of the inquiry process, we are not at a place where all teachers in classrooms demonstrate this same level of understanding. Therefore, more must be done to further the understanding of all teachers.

To summarize this section, many of the preservice and practicing teachers displayed some attributes of good, authentic inquiry. When looked at as a whole, eight main themes emerged to describe those positive indicators. However, this research also suggests that demonstrating pieces of the inquiry process were not enough to guarantee that there was full understanding of what it means to conduct authentic inquiry. If there was not synthesis of information and a sense of all the phases of the inquiry process working together, then the project tended to score lower and receive less positive comments. The following figure is a re-design of the Figure 2, which originally displayed the eight themes discovered in the comments. The new figure takes out the theme of Accurate Project Follow Through, under the assumption that this would be a requirement

for any project one undertakes, whether inquiry-based or not. Secondly, it changes from the original figure by taking the Synthesis of Information theme from being on the same level as all the other themes and bringing to the center of the process. It is the core piece that holds all the rest of the inquiry project together. If an inquiry project demonstrated all of these phases and effectively synthesized information gathered throughout the project, it could truly be described as an accurate example of authentic scientific inquiry.

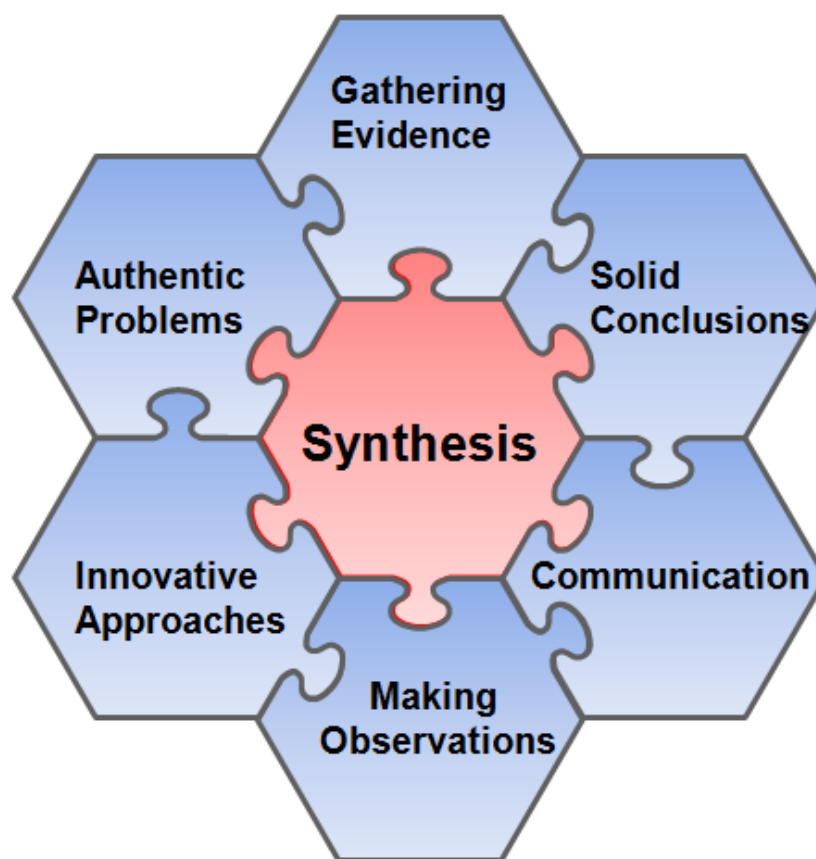


Figure 16. Revised Model of Essential Inquiry Components

This figure demonstrates how all the separate pieces of the inquiry process must be held together by synthesis. No part of the inquiry process can be done in isolation. All stages of the process work together and build upon each other reach defensible conclusions.

Suggestions for Teacher Educators Promoting Scientific Inquiry

The results of the current investigation indicate that the vast majority of teachers, both preservice and practicing, have many of the needed skills to successfully implement an inquiry investigation. Although many of the skills are present, those skills are not always integrated together to produce authentic scientific inquiry.

The first suggestion for teacher education programs, beyond the basic promotion of scientific inquiry as an instructional strategy, is to allow preservice teachers the chance to learn about and experience each of the phases of the inquiry process separately. Though the different phases must work together to reach defensible conclusions, it is important that the skills and function of each phase is well-understood. Findings in this study suggest that each phase of the inquiry process is an important link to the overall effectiveness of the intended inquiry. Strong positive correlation coefficients were discovered between each of five of the inquiry phases and the overall demonstrated understanding of the inquiry process. The only phase that did not display a strong positive correlation was Considers New Evidence. As discussed in the previous chapter, this phase had the lowest mean scores by a substantial amount. Even then, there was a moderate positive correlation between that phase of inquiry and the final overall score.

These strong correlations indicate that positive understanding of each particular phase has a strong impact on the overall project. Similarly, when a student showed a weaker understanding of each phase, there was generally a negative impact on the demonstrated understanding of the inquiry process. These findings imply that a full understanding of the each phase should be achieved before the entire process and goal of authentic scientific inquiry can be grasped. It is recommended that teacher educators take time to study each phase and provide opportunities to practice and improve on the skills needed in each phase.

Generating authentic and researchable questions is an important skill, and the successful completion of this phase sets the tone for the entire inquiry investigation. Students studying to be teachers need guidance and practice in creating questions and orienting themselves to solve a problem. This, in turn, is later passed on to younger students, but can only happen when the teacher in the classroom is able to do so. Time should be spent teaching future educators how to make observations of phenomena and in various settings. Some preservice teachers may have very little experience with making worthwhile observations that are used to further scientific understanding. Though preservice teachers likely have experience gathering evidence from other means such as books and websites, results of the current investigation indicate that many will need assistance with understanding how to bring that information together with observation to create more defensible conclusions.

Secondly, synthesis of information must be emphasized. The most successful projects had investigators who synthesized information effectively and efficiently. The

conclusions were more defensible because there were multiple pieces of evidence supporting them. Synthesis must be an overall theme that is emphasized throughout the instruction devoted to scientific inquiry. Inquiry can't be complete without synthesis. However synthesis can't really occur without the successful completion of each phase of inquiry. Therefore, as stated in the paragraphs above, it is important to teach each phase separately, but it's equally important to teach and demonstrate how to synthesize the phases together. Each phase must be taught and experienced, and then synthesis must be the overall theme that is emphasized.

Windschitl (2003) found that preservice teachers who had experienced authentic inquiry prior to full time teaching, showed more willingness and proper execution of inquiry teaching. Prior to experience with authentic inquiry, Windschitl (2003) described his preservice, teachers as students who “were unable to articulate a coherent model of inquiry” (p.118). Windschitl (2003) proposed that preservice teachers who experienced authentic inquiry experiences during preparation showed more willingness to implement inquiry-based methods on their practicum experiences. Therefore, Windschitl (2003) advised that it is critical provide some authentic inquiry experiences to preservice teachers within their science methods courses, or at least within some professional development. He said prospective teachers “must become familiar not only with criteria that define suitable inquiry questions (through authentic inquiry process) but they must have access to strategies for helping young learners understand and use the criteria” in classroom situations (p. 139-140).

A major goal of this research was to determine how well preservice and practicing teachers understand the inquiry process and to make suggestions for improvement in their educational preparation. Table 24 offers suggestions to alleviate some of the common problems or issues observed in this inquiry research. Each of the six separate phases of inquiry that were included in the evaluation instrument are included in this table, along with two other overall issues that were observed. Haug (2014) noted that there is a need for more explicit, concrete examples of inquiry-based classrooms in order to better understand how inquiry science is enacted in ways that promote student learning. Many of these suggestions relate to the use of direct, concrete instruction of each phase of the inquiry process.

Table 24

Summary of Major Issues in the Demonstrated Understanding of the Inquiry Process and Recommendations for Future Inquiry Assignments

Section of Inquiry Project	Major Issues	Recommendation to Solve the Problem in Future Inquiry Assignments
Orientation	<ul style="list-style-type: none"> • Weak links between questions and the rest of the investigation • Simplistic questions with known answers • Questions that cannot be answered through direct observation and interaction with the environment • Lack of planning when entering the investigation 	<ul style="list-style-type: none"> • Each of these issues could likely be addressed through targeted practice of creating research questions. Several example topics could be provided and students could be presented with a gradual release model in which, at first, the instructor writes the question to guide the research, and then provides guided practice for the preservice teachers. Finally, students would have independent practice with the skill, before actually undertaking their scientific inquiry project. These practice sessions should address the way observations can be utilized when answering the questions as well as how the questions will help guide the research. • The initial introductions to scientific inquiry would likely benefit from shared experiences and collaboration. Syer, Chichekian, Shore, and Aulls (2013) found that teachers entering the field need to learn about inquiry instruction by engaging in social discourse, in which they learn from their peers and more experienced members of the culture or group, and by also actually engaging collaboratively in inquiry.
Makes Observations	<ul style="list-style-type: none"> • Substituting existing facts from literature or Internet in place of personal observation • Neglecting to use background and personal existing knowledge to supplement observations 	<ul style="list-style-type: none"> • To better prepare students to make and then utilize personal observations, offer opportunities to observe phenomena, then work to make sense of those observations. An instructor could use video for the observation or take students into the field to make observations. Again, practice and explicit instruction are key to helping the preservice teachers become better observers.

(table continues)

Section of Inquiry Project	Major Issues	Recommendation to Solve the Problem in Future Inquiry Assignments
Gathers Evidence	<ul style="list-style-type: none"> Use of only one or two information sources 	<ul style="list-style-type: none"> Students need direct experience and exposure to different sources of information. The instructor should provide examples of information gathered from a variety of sources including, but not limited to, books, journals, the Internet, personal observation, video sources, and expert interviews. Students may need guidance in learning to identify and evaluate electronic information (Chung and Neuman, 2007). This is especially important when locating information that complements and supplements background knowledge and personal observations.
Considers New Evidence	<ul style="list-style-type: none"> No use of expert in the field to enhance information gathering Mistaking a non-expert friend or family member as an expert in a field. 	<ul style="list-style-type: none"> Students may need to receive information and suggestions about how to identify and locate experts in different fields of study. Actual names or general titles of positions may be provided. Examples may also be given to demonstrate how to contact someone who is not a personal acquaintance. This was typically the lowest scoring category on the evaluation rubric, often because authors of the projects just did not attempt it. Instructors taking time to emphasize this idea and provide guidance would have positive benefits by giving students more confidence to complete this step of inquiry.
Conclusion	<ul style="list-style-type: none"> Conclusions are based on only one type of information source Conclusions are not evidence of new understanding, just restating existing information 	<ul style="list-style-type: none"> This is another area of the inquiry process that would benefit from the use of a gradual release model. The instructor could offer several observations and related information as an example. The instructor would model the synthesis of the information to create a defensible, logical conclusion. Guided practice in this skill, then independent practice, would follow. Preservice teachers often find it difficult understanding how scientific arguments are constructed, transformed into written reports, and published for a wider, authentic audience (Zemba-Saul et al., 2002) Through this modeling process, the instructor should also present examples and non-examples of effective conclusions, emphasizing the difference between using information to make a new conclusion and just reporting a fact and presenting it as a conclusion. Branch and Oberg (2004) suggest encouraging student metacognition through planned and spontaneous reflections throughout the inquiry process to better allow students to understand what the gathered information is telling them, therefore leading to more defensible conclusions.

(table continues)

Section of Inquiry Project	Major Issues	Recommendation to Solve the Problem in Future Inquiry Assignments
Communication	<ul style="list-style-type: none"> • Errors in spelling, grammar, or formatting • Does not offer evidence of details that led to conclusions 	<ul style="list-style-type: none"> • Errors in spelling, grammar, and formatting will vary greatly with medium that is used to present the inquiry investigation. Much of this is dependent on students' work ethic. However, the instructor can liken the presentation method to the way scientists and researchers communicate their findings through journal articles. These articles are peer reviewed and edited to create the clearest picture of the research. The students should approach the final presentation of their research with the same mindset.
Topics	<ul style="list-style-type: none"> • Some topics generally did not lead to quality scientific inquiry 	<ul style="list-style-type: none"> • The current investigation found that some topics did not typically lead to as high a demonstrated understanding of the inquiry process as other topics. The two found to be the least effect were projects related to identifying clouds and identifying trees and leaves. Though it's unclear whether the topics themselves are less friendly to inquiry based investigation or whether it was the type of student who chose them, these two topics generally scored the lowest on the evaluation instrument. • Instructors need to be very clear with the expectations that differentiate an inquiry project from a fact finding research exercise. If identification projects related to clouds, trees, or leaves are to be allowed, guidelines must state actions that must occur for the investigation to be considered inquiry. When students receive initial guided practice during the orientation phase of the inquiry, they will better plan an authentic inquiry investigation.
Information Synthesis	<ul style="list-style-type: none"> • Projects lacked synthesis among the different phases of inquiry and various information sources 	<ul style="list-style-type: none"> • Effective synthesis of project work and multiple information sources was determined to be one of the main predictors of successful demonstration of scientific inquiry. Specific instruction must focus on synthesizing the different phases of inquiry, as well as the different sources of information used as evidence. • This problem of lack of synthesis was echoed in Moseley and Ramsey (2008) who found that graduate students being trained in inquiry had an incomplete view of inquiry and often overlooked the value of building connections within the process of inquiry. They suggested reflecting on the inquiry process in these areas: "a) inquiry is a coherent process consisting of particular actions, b) inquiry exists on a continuum, c) the goal of inquiry is science concept development, and d) inquiry provides a concept for building connections between those engaged in inquiry, science and other content areas, and science and life" (p.54).

Suggestions for Future Research

The sample used for the current investigation was comprised of both graduate and undergraduate students taking classes at the university. The samples of classes were from a range of years and semesters. However, all participants were tied in some way to the same university and were taught by the same instructor. It would be interesting to expand this sample in a number of ways. First, to further explore the inquiry process understanding of preservice teachers, this study could be replicated at another college or university to determine if inquiry process understanding remains fairly constant across instructors and education programs and to see if similar themes emerge regarding quality of demonstrated understanding of the inquiry process. Replication of project analysis such as this at other colleges or universities also may be beneficial as a program evaluation tool.

Another possibility for an expanded sample would be to look more closely at the characteristics of practicing teachers, such as the years they have spent in the classroom, grade level, or main subject area interest. The current investigation indicates that time in the classroom tends to improve a demonstrated understanding of the inquiry process. Deciphering which specific factors of classroom experience affect the quality of the inquiry project would be an interesting contribution to the literature.

This study relied on using inquiry projects of a certain design as determined by the professor who taught the course, both for undergraduate and graduate level students. Though the analysis instrument used in the current investigation was influenced by the assignment designed by the instructor, it also was designed to conform to inquiry

recommendations from other sources in the professional literature. Therefore, the analysis instrument should be transferable to assist in evaluation of any type of scientific inquiry project. It would be interesting to use the instrument to evaluate projects of a different design. The general inquiry concepts should not change, but the way in which they are carried out and presented could be much different.

A closer examination of the attitudes of both preservice and practicing teachers regarding scientific inquiry may reveal useful information. With much current emphasis being placed on achievement in reading and mathematics on standardized tests in public schools, do teachers see the value in taking the time to implement authentic scientific inquiry with fidelity? Attitude could have a lot to do future and current teachers taking the time and putting in the effort to fully understand the inquiry process. Teachers' attitudes toward inquiry may be improved through initial teacher preparation in university teacher education programs or through graduate programs and professional development for practicing teachers. A thorough understanding of teachers' attitudes may help guide such education programs.

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APPENDIX A
INSTRUCTIONS FOR THE OUTSIDE EVALUATOR

Thank you for agreeing to evaluate these teacher inquiry projects. Your efforts are assisting research into understanding how well practicing and preservice teachers demonstrate and understanding of the scientific inquiry process. Scientific inquiry is a process of finding answers to questions based upon observation and investigation. Student-centered scientific inquiry is much more than just doing prescribed experiments or letting students “run wild.” There is a process that must be understood and followed by the teacher. A lack of inquiry understanding by the teacher may lead to incomplete student learning.

Before you begin, it is important that you understand the process that goes into conducting scientific inquiry. Scientific inquiry is a quest for understanding the natural world based upon humans’ innate curiosity and desire to figure things out. Scientific inquiry is not the only form of inquiry that exists. Other forms of knowledge possess their own forms of inquiry and processes to gain new knowledge. Students work to solve problems, but also ask their own questions and process information to create their own understandings. Inquiry-based instruction is a student-centered, and aims to both support students in developing a deep understanding of scientific knowledge, facts, and concepts and to enhance students' abilities to reason and think autonomously. Learners work to identify big questions and use initiative to find relevant answers.

Inquiry is a complex activity involving several actions which are often cyclical in nature. Scientific inquiry involves making observations, posing questions, examining existing information on the subject, planning investigations, examining what is already known by observed evidence, using the correct tools to gather, analyze, and interpret data, proposing answers or explanations, and communicating results. Additionally, those involved in inquiry must be able to identify assumptions, use critical and logical thinking, and also consider alternative explanations.

There are many models that explain the scientific inquiry process. The evaluation instrument that was used for this project analysis was designed by the investigator and based upon the inquiry information students were given prior to the assignment completion. The instrument was guided by *Inquiry and the National Science Education Standards: A Guide for Teaching and Learning* (Center for Science, Mathematics, and Engineering Education, 2000). This text was the resource preservice and practicing teachers had when completing the assignment. All categories found within the instrument are referenced within Pedaste et al. (2015) and Windschitl (2008).

The instrument was divided into six categories consisting of the main phases of the inquiry process. These categories include Orientation/Driving Question, Making Observations, Gathering Evidence, Considering New Evidence, Conclusion, and Communication. Within each category are sub-categories that further describe attributes of inquiry that should be demonstrated.

Thirty projects have been randomly selected from the total 141 that were evaluated. These projects are all located on the accompanying flash drive under the file

named “Projects for Outside Evaluator.” Also on this flash drive is spreadsheet named “Outside Evaluator Spreadsheet” where you can record your scores for each descriptor. The rubric that accompanies these instructions will assist in making evaluations for each of the 24 descriptors within the six inquiry categories for each project. The rubric lists the attributes that may be found in the projects for each possible score, 1-5, for each descriptor. After viewing a project presentation, go to the Orientation section of the spreadsheet. Then look at the Orientation section of the scoring rubric. The heading on the scoring rubric should match the heading on the spreadsheet. Use the descriptions for each possible score to determine the score you think the project earned for this descriptor. Follow this process for all 24 descriptors, and then for each project that follows. Your work on this study is very much appreciated! Thank you.

APPENDIX B

SCORING RUBRIC FOR OUTSIDE EVALUATOR

Category: Orientation

Descriptor 1: Idea: Demonstrates the ability to form authentic, researchable question

Rating	Rating Criteria
5	Specific, researchable Answered with observation: strengthen with research Wide range to understand overall topic Guides Investigation / Project Addressed in conclusions
4	Not all questions are specific, but most are Good, but not direct tied to background Good, but too many little questions- 4+ Good questions, but not focus of research Interesting, but too broad to answer questions well
3	Simple answers Simplistic or answers likely known Not very observable (hard to observe) More suited to information search Questions that are not addressed Not focused / too broad / not related
2	Only slight tie to overall topic Not observable Answers already known Yes/No answers
1	Unrelated Does not ask questions

Category: Orientation

Descriptor 2: Ideas or circumstances that prompted the research question are explained

Rating	Rating Criteria
5	Evidence of authentic curiosity Detailed explanation of circumstances- unique situation that prompted reason Wants to know answers to satisfy real curiosity Personal, authentic reasons for research Good tie to research questions

4	Indicates sure background, less distracted Authentic reason to know more, but less detailed Well explained, but not perfectly tied to questions
3	Basic explanation, not overly personal or authentic Story but not profound Lack of depth/ detail
2	Missing a lot of detail Very generic reason for wanting to know more
1	No background given Background given but not tied to questions or investigation

Category: Orientation

Descriptor 3: Question posed can be answered through the proposed data collection

Rating	Rating Criteria
5	Sounds thorough, makes sense for goals Includes multiple data sources Detailed Match between questions and plans Includes thoughts on incorporating expert input
4	Well thought out, but may rely too much on inference or outside resources Good plan, but not enough time to implement Good insight May not address one of the questions but most questions are addressed
3	Plan relied almost exclusively observation or exclusively on outside sources- recipe for fact finding Ambiguous with few details More than one question not addressed in plan Disconnect between questions and plan
2	Questions cannot be answered with existing plan Lack of clear direction for investigation Questions not tied to data collection May only address one of multiple questions
1	No plan described Complete disconnect between topic, questions, plan

Category: Orientation

Descriptor 4: Question posed will lead to new understanding for the student-subject is likely not addressed in general K-12 education

Rating	Rating Criteria
5	Definitely or likely not covered in k-12 classrooms Completely unique case Case specific so wouldn't be covered Possibly only well known to experts
4	Possibly a topic taught, but brought to new level Takes a unique or personal spin on common topic Goes a little farther than k-12 Pieces are new, others might be covered by basic education Not address locally Descriptor language goes farther than typical
3	Maybe a covered topic- different way of going about it Not an uncommon topic Student likely already known answers
2	Common topic that doesn't address anything new Very basic ideas Simple identification
1	Doesn't seem to lead to any new understanding

Category: Orientation

Descriptor 5: Defines questions- demonstrates deep understanding of the question

Rating	Rating Criteria
5	Obvious experience with topic hoping for deeper understanding Right questions to lead to deep understanding Related to prior observations Understand more complex ways to address topics
4	Questions were thorough with some background shown Knew enough to ask good questions Admits to not knowing but asks good questions for full answers Some background allowed for pertinent information Prior experiences or observations

3	Basic understanding demonstrated Questions are broad, not complex Questions are appropriate Simple and answer is likely known Does not come back to questions Seems to simplify topic
2	Weak link between questions, plans, understanding Contradictions within questions or backgrounds Glaring misconceptions (doesn't know difference between tree/shrub) Questions don't go well, sloppy link of the concepts together
1	Questions are completely unrelated to topic, conclusions

Category: Makes Observations

Descriptor 1: Exhibits curiosity – looks at more than the bare minimum

Rating	Rating Criteria
5	Looks at multiple attributes and angles (>3) Conducts multiple experiments Goes beyond just identifying Multiple observation, multiple locations Goes beyond original questions High quality outside resources – beyond children’s books
4	Several lines of inquiry used (2-3) High quality resources More than one outside references used Appears to spend a lot of time looking for evidence Uses observations to conduct further research Looks deeper than questions would imply Observations go beyond minimum Looks at several aspects of ID (i.e. leaves, bark)
3	Few personal observations / more would be useful Leaves some pieces unanswered Didn’t go too far out of way for observations Simple, lacking substance or sense making Not all personal photos for ID projects One observation/one location/ faraway pictures
2	Almost entirely used existing sources Superficial, surface level observations Observation are misinterpreted Listed species without actually observing
1	No evidence of curiosity No listed species Unclear identified, superficial, surface level observations Observation are misinterpreted

Category: Makes Observations

Descriptor 2: Uses appropriate tools to gather evidence

Rating	Rating Criteria
5	Uses physical specimens, photos, and written resources Great mix of photos/observations and previous research Multiple photos for each observation Tools used beyond camera (Webcam, trailcam, and anemometers) Quality guides/back of previous research

4	Tools are appropriate find answers – will answers question Tools will gather good proof for conclusions 1 or 2 tools beyond camera and books
3	Lack of personal observational tools Basic (camera and books) nothing out of the ordinary Aspects of the plan may be hard to follow through with Relies more on existing facts
2	Tool used, but not in conclusions Lack of background information to assist sense making
1	No tools used Tool completely inappropriate for investigation

Category: Makes Observation

Descriptor 3: Observations lead to further, related, researchable questions

Rating	Rating Criteria
5	Great, natural extensions of the original questions, which shows a good understanding of the conclusions and what could be further investigated Natural authentic – not forced May provide pictures to detail extended interest Solidly logical follow-up Directly related to the investigation Higher-order, hypothetical
4	Interesting follow-up, possibly simpler than original Connected to conclusions, logical extensions Limited but related follow-up New questions may be better than original ones –more tied to conclusions Direct result of current investigation
3	Average extensions, nothing spectacular Related but not as specific as originals Not beyond what they already did Related but disjointed, less complex Hard to find answers to new questions
2	Weak, not researchable Restating original questions Less effective than originals
1	Observations do not lead to further researchable questions Observations are not relatable

Category: Makes Observation

Descriptor 4: Uses background/prior knowledge (use background knowledge to make observations or mentions background knowledge in some other context)

Rating	Rating Criteria
5	Investigation is based on prior experiences Background mentioned within each conclusion Mentions how background led to specific questions Multiple mentions throughout project
4	Basic enough understanding to ask good questions Mentions background experience several times Most conclusions include mention of background Background shared, though not leaned on heavily Background helped lead questions (Evidence of this) Referenced several times Displays familiarity with topic
3	Mentioned a couple times in the project (2-3) Discussed but not consistently through the project Alluded to, but not really used in conclusion A few minor mentions of background/not too deep Background mentioned but ignored – basic ideas made to look like big questions
2	Mention 3 or less times throughout Very little mention, vague, disconnected Brief mentions in the beginning only Seems artificial or forced
1	No background mentioned at all

Category: Makes Observation

Descriptor 5: Generates hypothesis, possible conclusions, or explanation

Rating	Rating Criteria
5	All conclusions include observational evidence Evidence is hard to refute from project Directly related to questions Ten great conclusions Build upon each other Observations of multiple aspects of the topic Built upon direct observations and research Expert confirmation (may have) Accompanied by lots of information and details
4	Conclusions based on observation and accepted information 6-7 are strong conclusions based on observations

	<p>Mostly good, but accuracy or quality of 1-2 may be in question Conclusions are good and observation based but not related to original questions Not all (2-3) based on personal observation</p>
3	<p>Sample ID Most conclusions could not have come from observation Several area just relating facts Observations used mostly to confirm facts found elsewhere Simplistic and possibly already known</p>
2	<p>Very basic, already known facts 2 or less conclusions Listing of Species Treats observation as a conclusion Forced base very simple</p>
1	<p>No hypothesis No conclusions No explanation</p>

Category: Gathers Evidence

Descriptor 1: Physically collects information through specimens, notes, photos.

Rating	Rating Criteria
5	Multiple personal photos, anecdotal observations Use other physical evidence Goes out into the environment – extended time Close up photos, no stock photos Unique examples of physical specimens
4	Majority of photos are personally taken May include some unique physical specimens May spend extended time in environment 1-2 may be stack photos, but good examples
3	May personal photos, but only some used for conclusions Usefulness of photos maybe in doubt Supplemental generously by stacked photos Basic observational notes Project is not dependent upon evidence personally gathered
2	A few personal photos or notes but most are from Internet Photos from the Web used to pave conclusions found on Web
1	No evidence of personal gathering

Category: Gathers Evidence

Descriptor 2: Photographic evidence is of high quality and beneficial to answering the posed question

Rating	Rating Criteria
5	All photos are clear and well formatted Close ups for detail/larger views for overall Arrows or graphics may be added to aid view Photos taken over extended time spam (May) Photos are thoughtful to make case for each conclusion of specimen ID
4	Good photos that help prove conclusions Most are high quantity, like a 5, but a few may be blurry or unfocused Some beneficial close ups Framing is generally good, though some need improvement
3	A few good photos, but many don't show necessary detail or proper framing Pictures are there but all look the same Good pictures but may not be helpful to the project A lot of found images are supplemented
2	Photos add very little to conclusions Photos are not correct features Much more found photos than personally taken
1	Conclusions lack photographic evidence No personal photos used anywhere in the project

Category: Gathers Evidence

Descriptor 3: Collects data through other means - books, Internet, experts

Rating	Rating Criteria
5	Multiple information sources used to explain observations Books, Internet, experts all combine Outside information sources used the cross reference with personally collected data Utilizes other reliable, unique sources of information Consults with other sources before, during, and after observation
4	Outside sources were essential for identification May rely more on outside sources than own observation Evidence in some conclusions that multiple data sources were utilized
3	Outside sources mentioned in the plan, but not actually used in conclusions Some conclusion have clear evidence, others have no evidence Consulted ID guide Relies almost exclusively on outside sources
2	Mentions other sources, but doesn't see to less the information on conclusion
1	Does not reference previous research

Category: Gathers Evidence

Descriptor 4: Uses previous research findings

Rating	Rating Criteria
5	Evidence that previous findings were applied to make new conclusions Nicely combined previous research with observations Previous research helps information observations and conclusions Mixed in at appropriate times Very specific with previous research sources PR helps to strengthen findings
4	Leans heavily on previous research to make conclusions Previous research is cited on several occasions Important information, but doesn't always supplement observation Less synthesis of information as a 5
3	Based almost entirely on previous research, which should not be sole source of information Might be assumed though not stated Mentioned only once or twice Uses ID book for strictly identification
2	Conclusions only have a vague reference or 2 to previous research Previous research is very simple or without credibility
1	No outside sources used All information comes from pure speculation

Category: Considers New Evidence

Descriptor 1: After talking to expert, considers new approach to the inquiry

Rating	Rating Criteria
5	Evidence of talking to real expert in the field Use new approaches based on this Uses ideas for making observations
4	Talks with a person who has a specialty or high interest in the field Shares 1 way information was used
3	Talks with a person who is casually involved with the field of study Mostly looking for confirmation May share a question this person also had
2	Talks with a friend or family member that may know more about the topic Looking mainly for confirmation
1	Does not consult any type of expert May mention doing this project plan but does not follow through

Category: Considers New Evidence

Descriptor 2: Incorporates new evidence into understanding

Rating	Rating Criteria
5	Specifically shares information about how corrected misconception Shows how new line of inquiry or new tool was used based on this expert Specifies how experts line of thought was different
4	Similar to 5, but less evidence Allows some changes based on expert Expert may be weaker Admits to both expert and student being stuck Mentions clearing up confusion
3	Inferences can be made from conclusions Cites confirmation but not changes Close to 4 but “Level 3” expert
2	Nothing specifically stated through some inferences could be reached Talked to expert but gave no report on how this affected investigation New evidence is presented but ignored in conclusion
1	No change noted or alluded too No expert actually consulted

Category: Conclusion

Descriptor 1: Interprets data - Did they combine physical/photo evidence with existing expert data to come to a new understanding.

Rating	Rating Criteria
5	Excellent balance of observation and existing information Prolifically mentions observations then research, the conclusion Effective synthesis of observation and existing information Evidence of several data sources being used to make claims- how existing information helped to make sense of observations, leading to conclusions
4	Brings research and observation together well 1 or 2 cases where it's not as clear that multiple information sources were used Possibly front loaded existing, but did use as much in synthesis to create conclusions Possibly 1 or 2 are overwhelming with information could be broken into 2 or 3 separate.
3	Based almost solely on either observation or existing information Information sets are found as separate little synthesis A few conclusions off nice synthesis but the majority do not
2	Lack of one type of information Inclusions of contradictory information Mistakes observations for conclusions
1	Pure fact finding No attempt to synthesize

Category: Conclusion

Descriptor 2: Synthesizes more than one line of evidence to come to new understanding

Rating	Rating Criteria
5	Effectively brings many lines of evidence together Evidence that observations, photos, existing information used Multiple information sources cited in conclusions to come to full conclusions
4	Multiple information sources utilized, though synthesis may be lacking in a few conclusions Evidence of observation data and research being used Specifics may not be given on 1 or 2
3	Several sources listed though not synthesized as well in more than half Used multiple sources, but only one source at a time in conclusions, lack synthesis Educates physical attributes that match guide book
2	Basically uses only one information source One line may be very weak Lists into sources without interpretation or synthesis
1	No observations and one source of existing No evidence of any kind of synthesis

Category: Conclusion

Descriptor 3: Bases conclusions on own observations (Consulting books/Internet/experts is okay)

Rating	Rating Criteria
5	Personal observations are always mentioned in every conclusion Large numbers of personal photos and observational notes Observations are basis, then previous research consulted May even discuss disagreements between observations and previous research
4	Lots of personal photographs and observational notes Describes own observations, but may not always be used as the basis for conclusions All but 1-2 have ample amounts of personal observation data
3	Observation begin the process but conclusions may not be the base for conclusions Indicates observation but more used to continuation information found in research Some conclusions (3-4) may be lacking any evidence of personal photos
2	Many (6-9) conclusions have no personal observation Most conclusions appear based on the other sources Little evidence at observation coming first, mostly fact finding Personal observation not used conclusions or no interpretation
1	No observation used in any conclusion, complete fact finding

Category: Conclusion

Descriptor 4: Adds to explanation of phenomenon

Rating	Rating Criteria
5	Really explored the topic and presented detailed conclusions Student has much better understanding and shows it effectively Relates specifically to research questions and gives solid answers Possibly case specific, but really increases understanding to this unique case
4	Adds to explanation for particular case Explanation is expanded for the student May not be new information, but student makes better sense of personal environment Offers unique perspective of unique case
3	Adds to personal understanding, but not anything new to general body of knowledge Much may have been in guidebook but student has better understanding Some conclusions may be incomplete, not adding much Helps student, but information is likely known by many
2	Not much new comes from this Since mostly based on previous research, student seems to just be reporting, not newly understanding Some incorrect information Minimal actual new findings
1	No observation of adding any explanation of phenomenon

Category: Conclusion

Descriptor 5: Demonstrates an ability to transfer application to use in an elementary inquiry-based classroom

Rating	Rating Criteria
5	All activities are age appropriate, related to the project and student-centered Fantastic extensions of the project and area fully inquiry based May be experimental, require multiple information sources
4	2 of the activities are great extensions that use hands-on student-centered inquiry Activities are interesting and innovative, but may be unrealistic or hard to follow through with Higher order, may incorporate cross curricular skills
3	One really well thought out student-centered inquiry project Projects lack fun and interesting, but are more of a craft than inquiry Attempts to be inquiry-based, but is more information meaning
2	Simple and basically crafts Not fully related to the main project Vague and uninspired ideas Not all realistic to classroom settings Very little to no inquiry involved
1	No ideas listed Not related to the project

Category: Communication

Descriptor 1: Presentation is aesthetically pleasing enough to effectively communicate process and findings of the inquiry investigation.

Rating	Rating Criteria
5	Colorful, interesting to look at Thematic colors and custom made background tie everything together Polished look with easy to follow design
4	Looks professional and easy to read Like a 5, expect a few photos were fuzzy and may contain 1-3 spelling or grammar errors Colorful and easy to read
3	An acceptable presentation but may be bland or unexciting to look at More than 3 spelling or grammar errors Some pictures are too small or too blurry to be effective Nothing is overly detracting, just not above what is required
2	Multiple spelling, grammar, and formatting errors that detract from effectiveness Did not erase instructors work from the template
1	So many spelling and grammar errors, the project does not communicate effectively The project as a whole does not flow or connect

Category: Communication

Descriptor 2: Presentation contains quality information, supported by enough detail to make claims.

Rating	Rating Criteria
5	Excellent mix of research and observation data Each claim is accompanied by extra information and facts More than enough details and personal observations to make claims Includes descriptive information from research that matches observation
4	Lots of information but may be lacking either research or personal observation Some conclusions may not be sufficiently supported by gathered evidence When ID project, there is extra specific information for each specimen
3	Mentions observations, but not clear where big ideas come from Not enough observational or expert data included in 4-5 of the conclusions Most information comes from existing sources A few incorrect statements or captions Information has too much conjecture
2	Very little evidence to support claims Not enough information provided to make credible claims Observations are interpreted incorrectly
1	No quality relevant information supported by enough detail No claims made

Category: Communication

Descriptor 3: Organization is logical and effective

Rating	Rating Criteria
5	Conclusions appear in groups and build off of each other Seems to really be through Logical pattern can be seen in presentation May follow the order of the original questions
4	Organization generally makes sense and no problems detracted One or two conclusions may seem to be out of place Generally, well laid out and easy to follow
3	Organization was okay, but lacks depth Nothing about organization detracts but nothing stands out Several slides could be reorganized to make better sense An effort made to present in a way that made sense
2	Lack of logical organization Viewer forced to go back and forth between slides to make sense
1	So little logical organization, no sense can be made Appears to just write about any thoughts

